2 Description of Quabbin Reservoir Watershed Resources

2.1 DCR/MWRA Water Supply System

2.1.1 System Description

The Department of Conservation and Recreation, Division of Water Supply Protection, Office of Watershed Management and the MWRA supply drinking water to 40 communities in the metropolitan Boston area. The Town of Clinton also draws water from Wachusett Reservoir, independent of the MWRA transmission and treatment system. Two communities near Wachusett Reservoir, Worcester and Leominster, may also withdraw water from the system for emergency supply. In addition, three communities southwest of Quabbin Reservoir (Chicopee, South Hadley Fire District #1, and Wilbraham) obtain their water directly from this reservoir through the Chicopee Valley Aqueduct. MWRA is responsible for treatment and transmission, while the Division is responsible for collection and safe storage of water, protection of reservoir water quality, and management of the watersheds.

Figure 1 presents a system schematic. Quabbin Reservoir, the Ware River, and Wachusett Reservoir are the active water supply sources for the metropolitan Boston water system. Ware River water is transferred seasonally to Quabbin Reservoir, while Quabbin Reservoir water is transferred regularly to Wachusett Reservoir through the Quabbin Aqueduct. Wachusett Reservoir is the terminal supply reservoir. Water is withdrawn through the Cosgrove intake at the eastern end of Wachusett Reservoir, and is carried by the Cosgrove Tunnel to the distribution system. The Wachusett Aqueduct provides redundancy to the Cosgrove Tunnel; it was used during the winter of 2003-2004 to allow connections to be made to MWRA's new Walnut Hill Treatment Plant.

The Sudbury and Foss (Framingham #3) Reservoirs are the emergency reserve water supplies for this system. There are three emergency conditions that would require the use of the Sudbury System: 1) Wachusett Reservoir is declared non-potable; 2) there is an inability to convey water from the Wachusett Reservoir to the MWRA system (e.g., failure of the Hultman Aqueduct, Southborough Tunnel, or the City Tunnel); or 3) a serious drought occurs.

Depending on the situation, the Sudbury Reservoir would be used either as a primary source of water supply, as a pass through of Wachusett Reservoir water, or as a supplemental source to the Quabbin and Wachusett Reservoirs. The past decade's withdrawals from each source water supply are summarized in **Table 5.**

Table 5: DWSP Watershed Areas and Withdrawals from System Sources, 1990-2000

Source	Watershed Area[1]		Average Annual Outflow[2] (mgd)	Average Annual Withdrawal (mgd)
	Sq. miles	Acres		
Ware River (MWRA Intake)	96	61,740	110	8.08[3]
Quabbin Reservoir	187	119,940	195.2	137.9
Wachusett Reservoir	117	74,890	127.4	123.1
Total DCR/MWRA Water Supply System	401	256,570	432.6	261

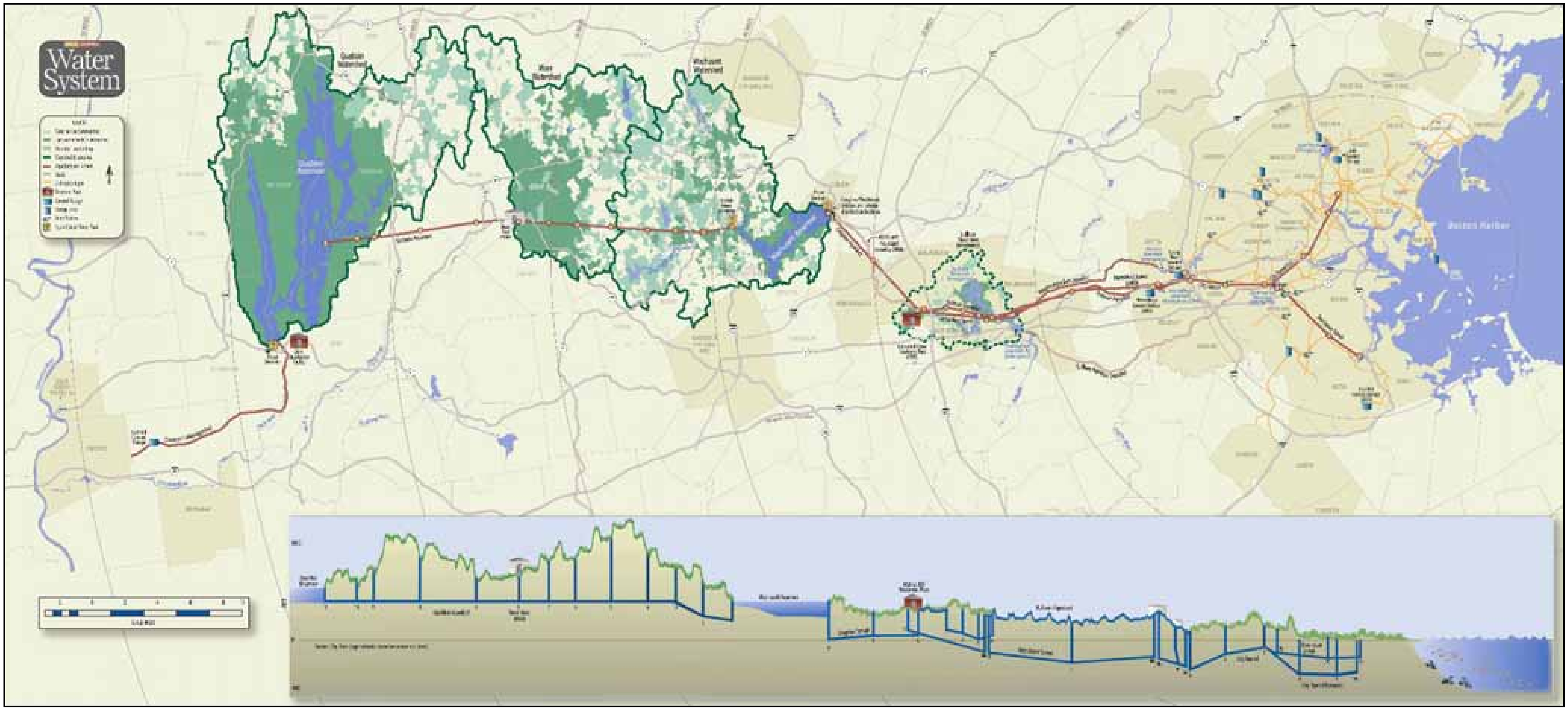
Source: Watershed Statistics – DCR/DWSP/OWM GIS; Water Withdrawal Statistics: MWRA, 2003

1 Including area of reservoir surface for Quabbin Reservoir and Wachusett Reservoir.

2 Outflow includes withdrawals and downstream releases

3 This is not a supply but a transfer to Quabbin Reservoir.

Figure 1: MWRA Water Supply System Schematic



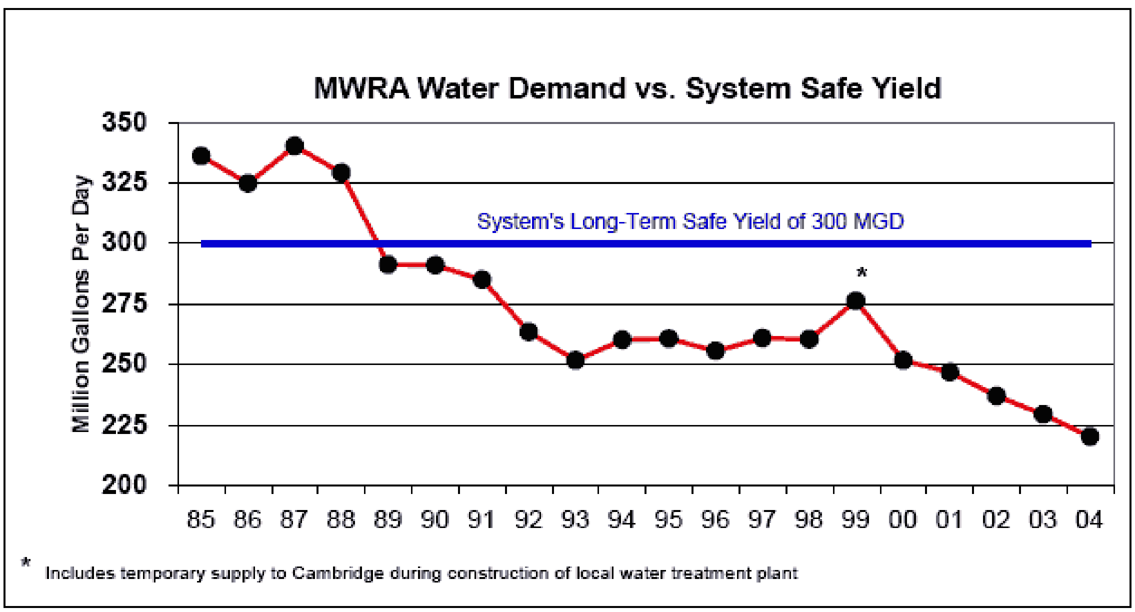
2.1.2 Safe Yield Estimation Model

Over the years, models and plans have been developed and refined to evaluate the MWRA system capacity. A Safe Yield Model was developed in the early 1980s that simulated inflow and outflow of water into the reservoirs using data for fifty years. It concluded that the safe yield was 300 million gallons a day (mgd).

Demand on this system was 225 mgd in 2005. This figure follows a fifteen year trend of diminishing water use in metropolitan Boston (**Figure 2**) and reduced MWRA demand, which had peaked at close to 350 mgd in the early 1980s. According to the MWRA, this reduction in average water use has been achieved through:

1. Vigorous leak detection and repair efforts on MWRA and community pipes.
2. Retrofitting 370,000 homes with low-flow plumbing devices.
3. A Water Management Program for businesses, municipal buildings and nonprofit organizations.
4. Extensive public information and school education programs.
5. A change in the state plumbing code requiring new toilets to be 1.6 gallon per flush.
6. Meter improvements that helped track and analyze community water use.
7. New water-efficient technology that has created reductions in residential use.
8. Water pipeline replacement and rehabilitation projects throughout the MWRA and community systems.

Figure 2: MWRA Water Demand vs. System Safe Yield



Source: MWRA

Maintaining the successful watershed management and water conservation programs will keep an adequate amount of excellent quality drinking water available to the MWRA user communities for the foreseeable future.

2.1.3 *Quabbin Reservoir*

2.1.3.1 Morphology and Bathymetry

The Quabbin Reservoir is a long reservoir with two main longitudinal sections linked by a narrow channel, the Enfield Channel. Morphometric characteristics comparing the Quabbin Reservoir with the Wachusett Reservoir are presented in **Table 6**. The bathymetry of a reservoir is a measurement of its depth from the water surface (generally at maximum elevation, i.e., when the reservoir is at its fullest), and is an expression of the topography of the reservoir floor. At full elevation of 530 feet above mean sea level, the deepest point in the Quabbin Reservoir is 151 feet below the surface, and the average depth is 45 feet. A bathymetric profile of the reservoir is shown in **Figure 3.** This bathymetry was derived from terrain elevations surveyed in the 1920s, in advance of the construction and filling of the reservoir. These surveyed data consisted of 140,480 elevation points, mapped out on 81 individual canvas map sheets overlapping the reservoir, a dataset that was recently converted to a digital reservoir elevation geodatabase.

Table 6: Morphology of Quabbin and Wachusett Reservoirs

Attribute	Quabbin Reservoir	Wachusett Reservoir
Volume Capacity	412 billion gallons[1]	65 billion gallons
Surface Area	38.4 square miles	6.5 square miles
Watershed Area	187 square miles	107.69 square miles
Shoreline	181 miles (61 on islands)	37 miles
Length	18 miles	8.5 miles
Maximum Width	3 miles	1.1 miles
Mean Width	1.5 miles	0.7 miles
Maximum Depth	151 feet	128 feet
Mean Depth	45 feet	49 feet
Normal Operation Range	520-530 feet	387-392 feet
Intake Depth[2]	442 feet[3]	364 & 345 feet
Overflow Elevation	530 (528) feet[4]	395 feet

Source: (DCR/DWSP – Civil Engineers Records, 2000)

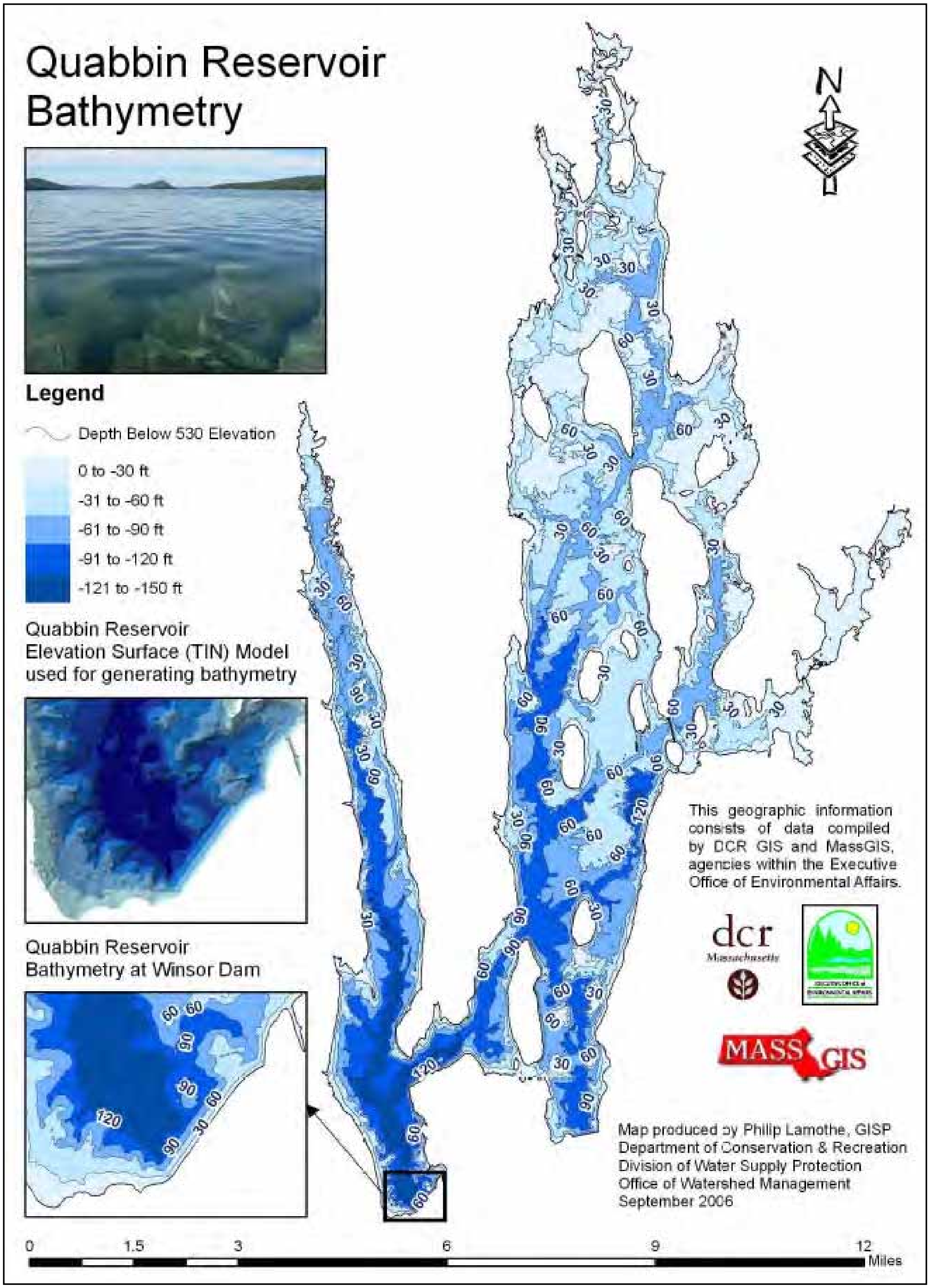
1 This volume is based on an overflow elevation of 530 feet

2 Datum used is Boston City Base (BCB) which is 6.049 feet lower than USGS 1929 datum used for topographic mapping.

3 Intake for Quabbin Reservoir is for Quabbin Aqueduct. This is the elevation between the portal invert and the shaft floor.

4 When stop logs are in place the overflow elevation is 530 feet. When the logs are removed the elevation is 528 feet.

Figure 3: Quabbin Reservoir Bathymetry



2.1.3.2 Inflows and Outflows

Inflows and outflows for Quabbin Reservoir are listed in **Table 7;** outflows are listed in **Table 8**. There are currently two continuous stream gauging locations within the Quabbin Reservoir watershed: the East Branch of the Swift River (1937-present), and the West Branch of the Swift River (1995-present). There is also a long stream gauging record at Cadwell Creek (1961-1997), which was discontinued in 1997. Tributary inflows were estimated for this assessment by doing a stream gauge transposition using the flows recorded by the gauges at the East Branch of the Swift River and Cadwell Creek.

Direct precipitation accounts for almost 30% of the average annual inflow. Inflows from Quabbin Reservoir's main tributary, the East Branch of the Swift River, and direct inflow follow direct precipitation in magnitude and, combined, account for about 34% of the annual inflow (on a long-term basis). Ware River transfers are also a significant source of inflow, at about 9% of the annual inflow.

The largest outflow from Quabbin Reservoir is the Quabbin Aqueduct withdrawal for transfer into Wachusett Reservoir, which accounts for more than 60% of water that leaves the reservoir. Other significant outflows are evaporation and downstream release to the Swift River, which together account for another ~30% of the outgoing water. Other smaller outflows include Chicopee Valley Aqueduct withdrawals for the Chicopee Valley Service Area and the flow over the reservoir's spill way, which occurs when the reservoir is full or almost full. In 1999, water transfers to the City of Worcester were additional outflows from the system.

DWSP and MWRA may divert water from the Ware River watershed at the Ware River Intake (Shaft 8) either to the Quabbin Reservoir or the Wachusett Reservoir through the Quabbin Aqueduct. The water enters the system at Shaft 8 on the Quabbin Aqueduct in the town of Barre, Massachusetts. Under normal operating conditions, the Ware River water flows to the Quabbin Reservoir through the aqueduct and is discharged at Shaft 11A, where the baffle dams force the water to flow several miles to reach Shaft 12 of the Aqueduct or further to the Chicopee Valley Aqueduct. It takes 3-4 years for water entering the Reservoir at Shaft 11A to travel to Shaft 12. In the past twenty-five years, there have been twenty-one annual diversions directly from the Quabbin Reservoir to the Wachusett Reservoir, and eighteen annual diversions from the Ware River intake to the Quabbin Reservoir. Currently, water transfers from the Quabbin Reservoir account for over 50% of the average annual inflow to Wachusett Reservoir. Transfers of approximately 550 mgd are made as needed to maintain the Wachusett Reservoir surface levels. These transfers occur primarily in the summer and fall months, are not continuous, and last for a period of several weeks at a time.

2.1.3.3 Hydrodynamics

A reservoir's hydrodynamics refers to the characteristic fluid motions of its waters during different seasons, under the range of local meteorological conditions (prevailing winds, temperature, storm events) and as influenced by the bathymetry and intricacies of the basin's shape. Residence time for reservoir waters, determined through hydrodynamic analysis, can influence risks associated with the transport of suspended sediments, pathogens, or other pollutants. The average residence time for water in the Quabbin Reservoir is about 4 years, defined generally as the reservoir volume divided by the annual inflows.

The reservoir is dimictic, turning over or mixing completely in the fall (usually in October), and again in spring in the period immediately following ice-out (usually in April). Quabbin develops some ice cover, usually between January and March, but occurring as early as December or as late as April. Inflows tend to move into different depths depending on seasonal temperature differences between the tributaries and the reservoir. Tributary inflows are typically warmer than the reservoir in the spring and therefore enter the reservoirs' epilimnion (stratified lakes are described as having three zones: the upper epilimnion, the metalimnion (commonly called the thermocline), forming a boundary between waters of different temperature; and the bottom hypolimnion)**.** In the summer and fall, tributary water is generally cooler than the reservoir's water and enters the reservoir below the epilimnion.

Table 7: Inflows to Quabbin Reservoir

Inflow Sources	Area (sq. mi.)	Annual Flow (cfs)	Annual Flow (mgd)	Annual Flow (%)
Direct Precipitation to Reservoir Surface	38	125	81	28
Ware River Transfers	96	39	25	9
Direct Inflow	40	78	51	17
East Branch Swift River	44	75	49	17
West Branch Swift River	12	24	16	5
Middle Branch Swift River	11	21	14	5
East Branch Fever Brook	9	17	11	4
West Branch Fever Brook	5	9	6	2
Hop Brook	5	11	7	2
Dickey Brook	4	8	5	2
Other tributaries	20	40	26	9

Table 8: Outflows from Quabbin Reservoir

Outflow Sources	Average Flow (cfs)	Average Flow (mgd)	Average Flow (%)
Quabbin Aqueduct	238	154	63
Chicopee Valley Aqueduct	18	12	5
Evaporation	68	44	18
Downstream release	42	27	11
Spillway	9	6	2

2.1.4 *Overview of Quabbin Water Works*

Winsor Dam (left) and Quabbin Administration building (right).

2.1.4.1 Winsor Dam and Goodnough Dike

Winsor Dam, located next to the Administrative Building, was built between 1935 and 1939. It is 2,640 feet in length, 35 feet wide at the top and 1,100 feet wide at the bottom, and required 4 million cubic yards of fill. It was named for Frank E. Winsor, the Chief Engineer for the Metropolitan District Commission from 1926 until his death in 1939. Winsor Dam impounds the waters of the Swift River, the primary source for the Reservoir, which first filled to the height of the spillway on June 22, 1946, reaching its full elevation volume of 412 billion gallons at that time.

Goodnough Dike

Goodnough Dike was built between 1933 and 1938. The Dike is 2,140 feet in length, 35 feet wide at the top and 878 feet wide at the bottom and contains 2.5 million cubic yards of fill. The Dike impounds the waters of Beaver Brook, which formerly flowed north through Morton and Sunk Ponds to the East Branch of the Swift River. It is considered a “dike” because it prevents the overflow of the lowlands surrounding Beaver Brook, rather than directly damming that tributary’s flow. The Dike was named after the Metropolitan Water and Sewer Board’s chair during 1921, X. Henry Goodnough.

2.1.4.2 Outlets and Aqueducts

Water leaves Quabbin Reservoir by gravity through two outlets: Shaft 12, which is the entrance to the Quabbin Aqueduct, and at the intake for the Chicopee Valley Aqueduct in front of Winsor Dam.

During the 1930s, the Wachusett-Coldbrook tunnel, which brought water from the Ware River to the Wachusett Reservoir during high flow periods, was extended westward to the Swift River. Shafts 11A and 12 connect this extension, known as the Quabbin Aqueduct, to Quabbin Reservoir. It is a two-way tunnel: floodwater can be skimmed and sent west from the Ware River to the Quabbin Reservoir as needed during eight months of the year, entering Quabbin at Shaft 11A, or water can be sent from Quabbin Reservoir to the Wachusett Reservoir, leaving Quabbin at Shaft 12 and flowing east through the same aqueduct. Ware River waters entering Quabbin Reservoir at Shaft 11A are diverted north around Mount Zion by baffle dams, allowing the settling of sediments and the mixing of these waters before they leave Quabbin Reservoir at Shaft 12.

Water from the Quabbin Reservoir flows through the Quabbin Aqueduct from the Northeast side of the Quabbin, up a grade to the Ware River Diversion in South Barre, Massachusetts, and then down grade to the Wachusett Reservoir through a power station near the Oakdale section of West Boylston, Massachusetts. This flow occurs by natural siphon action, the high point in the siphon being at the Ware River Diversion. At full elevation, the water surface of the Quabbin Reservoir is about 530 feet above mean sea level (MSL), while the water surface of the Wachusett Reservoir is about 384 ft above MSL, and the water surface of the Ware River Diversion is about 660 ft above MSL.

A natural siphon can only lift water about 30 feet, so the aqueduct is several hundred feet underground in several places so that the water head is only about 25 feet within the suction side of the aqueduct. The siphon starts at the Ware River Diversion by feeding the river water into the aqueduct. If the aqueduct branch that goes to the Wachusett Reservoir is closed (the Wachusett-Coldbrook branch), the Ware River water feeds the Quabbin Reservoir for storage. If the Wachusett branch is open, the water flows in both directions. Once the Wachusett branch begins to create sufficient suction as it fills, the Ware River Diversion inlet is closed and the water flow from the Quabbin to the Wachusett Reservoirs continues as a natural siphon.

The Quabbin Aqueduct, at 24.6 miles in length is one of the longest tunnels in the world and just ½ mile short of the Hetch Hetchy Aqueduct. It is 11 feet wide and 12 feet 9 inches tall, carrying water from the Ware River to Quabbin Reservoir or from Quabbin Reservoir to the Wachusett Reservoir, from which water is delivered to 41 metropolitan Boston communities.

The Chicopee Valley Aqueduct (CVA) carries water from Quabbin Reservoir to the Chicopee city line. Legislation authorized the construction of this aqueduct in 1947 and construction was completed by 1950. The CVA is 13.1 miles long and carries a diameter of 48 inches for 4.5 miles and 36 inches for 8.6 miles. The CVA delivers Quabbin water directly to Wilbraham, South Hadley Fire District #1, and Chicopee.

2.1.4.3 MWRA Water Treatment Facility for the Chicopee Valley Aqueduct

Water delivered to Wilbraham, South Hadley Fire District #1, and Chicopee is treated at the MWRA Water Treatment Plant in Ware, MA. This facility, which came on line in 2004, uses measured doses of chlorine to disinfect the water arriving from the Quabbin Reservoir, and adds chloramines to continue to protect the water as it is carried long distances via the CVA from the Reservoir to the receiving towns.

2.2 Quabbin Reservoir Watershed Ownership and Land Use

2.2.1 Current Land Uses

Among the most important aspects of the Quabbin Reservoir watershed for the protection of its waters as drinking supply is the nature of the land cover / land use of this watershed. As shown in **Table 9**, a full 93% of the watershed is in forest or wetland cover, and less than 5% of the watershed has been developed for agricultural, residential, or commercial / industrial purposes. Population density on the Quabbin watershed is fewer than 20 people per square mile, while the density on the Wachusett watershed, by contrast, is approaching 300 people per square mile.

Table 9: Land Cover, Land Use, and Population Density by Watershed

	Land Cover/Land Use (%) Excluding the Reservoirs							
Watershed	**Forest**	**Wetland**	**Agriculture**	**Residential**	**Commercial/Industrial**	**Open Water**	**Other**	**Persons per sq. mi.**
Quabbin Reservoir	87	6	3	1	0.1	0.3	3	16
Ware River	75	11	5	3	0.2	3	4	77
Wachusett Reservoir	67	8	8	9	0.6	2	7	284
Total	***77***	***8***	***5***	***4***	***0.3***	***2***	***4***	***109***

Source: (MDC, MWRA, and CDM, 1997)

2.2.2 Ownership

DCR owns the most sensitive lands within the 119,935 acre watershed of the Quabbin Reservoir, defined as the lands directly surrounding the reservoir and lands within 400 feet of tributaries to the reservoir. Including the 24,581 acre reservoir surface (21%) and 53,987 acres of watershed land (45%), DWSP presently controls 66% of the Quabbin Reservoir watershed (note that DCR/DWSP also controls 4,425 acres of land that are adjacent to but outside of the watershed boundary). Excluding the surface area of the full elevation reservoir, DWSP presently controls 57% of the land surface within the watershed. In addition, 17,163 acres (18% of the watershed land) is protected by other governmental agencies and private/non-profit groups (**Tables 10 - 12**).

Table 10: DCR/DWSP Land Holdings and Other Protected Watershed Lands

	Ownership as % of Watershed*		
DCR/DWSP Watershed	**DCR/DWSP -Owned**	**Other Protected****	**Total Protected**
Quabbin Reservoir	57	18	74
Ware River	38	20	57
Wachusett Reservoir***	29	26	52
Total	**43**	**21**	**64**

Source: (DCR/DWSP-GIS, 2003)
* Watershed area excluding reservoir surface.
** Includes lands owned by other state agencies, local government, and private entities; excludes Ch. 61 and Stewardship lands.
*** Includes 2,213 acres owned by DCR Division of State Parks and Recreation under a Care and Control MOU.

2.2.2.1 Public Lands

In addition to the 53,987 acres of land under DWSP control in the watershed, there are 8,207 acres under the care and control of other state agencies (5,395 acres **- Table 11)** and municipalities (2,812 acres). 2,381 acres are under the control of the DCR Division of State Parks and Recreation and the DCR Bureau of Forestry, primarily in the Shutesbury and Federated Women's Club State Forests, but also including portions of four other State Forests. The DFG Division of Fisheries and Wildlife controls 3,015 acres of land in the watershed, within six Wildlife Management Areas that intersect the watershed boundary.

Table 11: Public Agency Land Holdings within the Quabbin Reservoir Watershed

Agency/Areas	Acres
DCR DIVISION OF STATE PARKS AND RECREATION DCR BUREAU OF FORESTRY	
Federated Women's Club State Forest	936.0
Shutesbury State Forest	729.6
Wendell State Forest	535.7
New Salem State Forest	146.4
Petersham State Forest	32.8
Sub-Total	2,380.5

Agency/Areas	Acres
DFG – DIVISION OF FISHERIES AND WILDLIFE	
Philipston Wildlife Management Area	1,670.0
Popple Camp Wildlife Management Area (Petersham)	851.1
Raccoon Hill Wildlife Management Area (Barre)	286.8
Other Barre Wildlife Management Areas	81.5
Wendell Wildlife Management Area	73.3
Petersham Wildlife Management Area	52.1
Sub-Total	3,014.8
TOTAL	***5,395.3***

2.2.2.2 Private Lands

2.2.2.2.1 Protected Lands

Privately owned lands within the watershed that are currently protected from development include holdings owned by Harvard University, the Massachusetts Audubon Society, and the Trustees of Reservations. These holdings currently total approximately 17,200 acres.

2.2.2.2.2 Developed and Developable, Unprotected Lands

Less than 5% of the Quabbin Reservoir watershed is currently developed, with approximately 62,800 acres of the forests and wetlands either owned by DCR/DWSP for water supply protection or by other state agencies for a variety of functions. 24% of the watershed (28,846 acres) is privately owned forest land and could be developed in the future for residential, commercial, industrial or other land uses if permitted by zoning laws. The cumulative amount of development that is expected in the watersheds is much lower than the current amount of available "unprotected" land. The rate of development depends on many social and economic factors, including development pressure, the need or willingness of current owners to sell their land, and population growth. DCR also protects watershed lands from development through acquisition of conservation restrictions (CRs) and DCR currently holds approximately 716 acres of CRs in the Quabbin Reservoir watershed.

Table 12: Land Ownership within the Quabbin Reservoir Watershed

Owner	Land Acres	Reservoir Acres	Percent of Watershed	Percent of Watershed Area Excluding Quabbin Reservoir
DCR DWSP	53,987	24,581	66%	57%
Other Public	8,207	0	7%	9%
Private	32,833	0	27%	34%
TOTAL	**95,027**	**24,581**	**100%**	**100%**

2.3 Physical Characteristics of Quabbin Watershed Lands Under DWSP Control

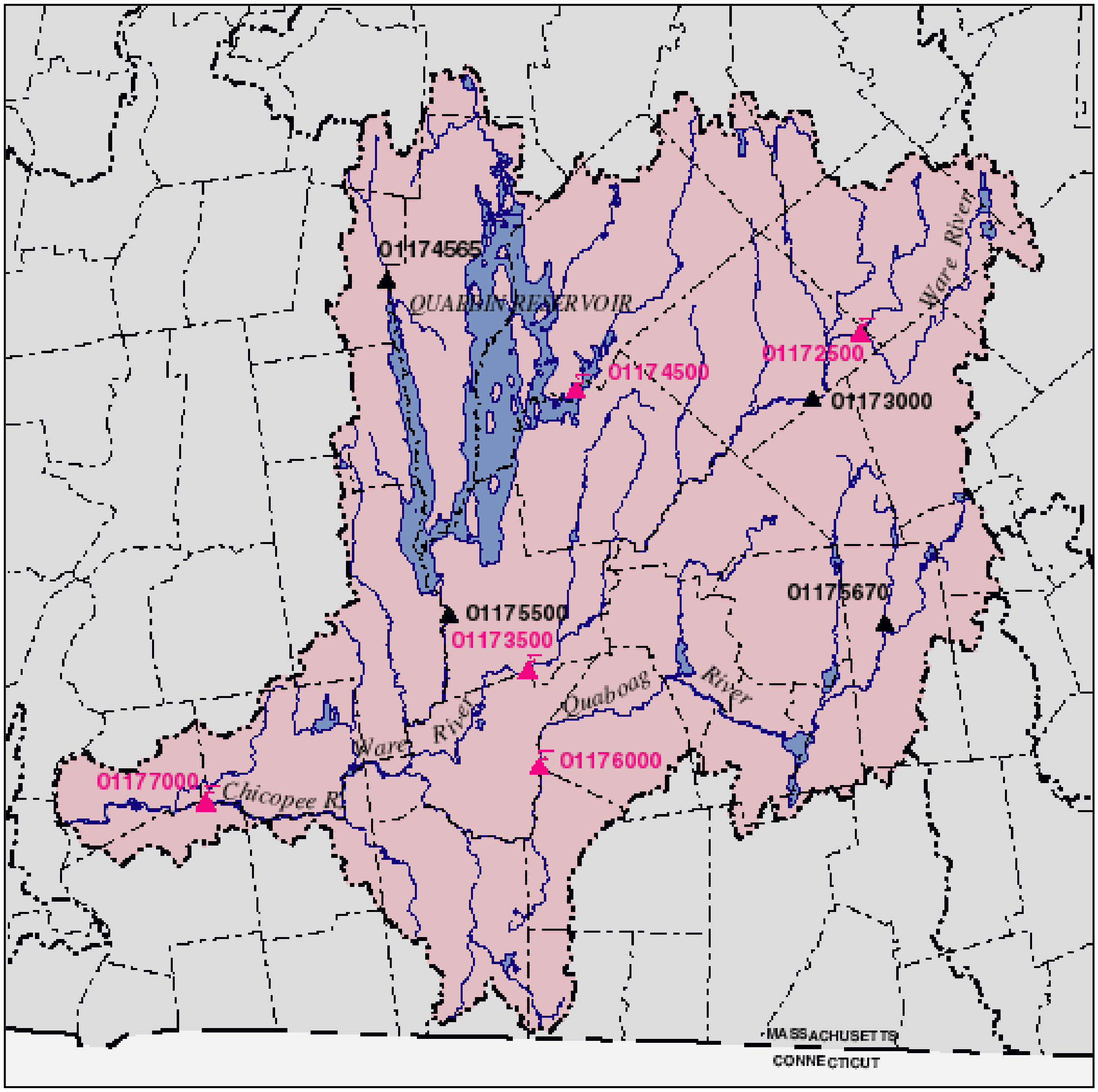
2.3.1 Watershed Delineation

The Quabbin Reservoir is situated within a hierarchy of basins, watersheds, and subwatersheds as described below and depicted in **Figures 4 - 8**.

2.3.1.1 Basin

The 721 square mile Chicopee River Basin includes the lands draining to four major river systems, the Swift River, the Ware River, the Quaboag River, and the Chicopee River (**Figure 4**).

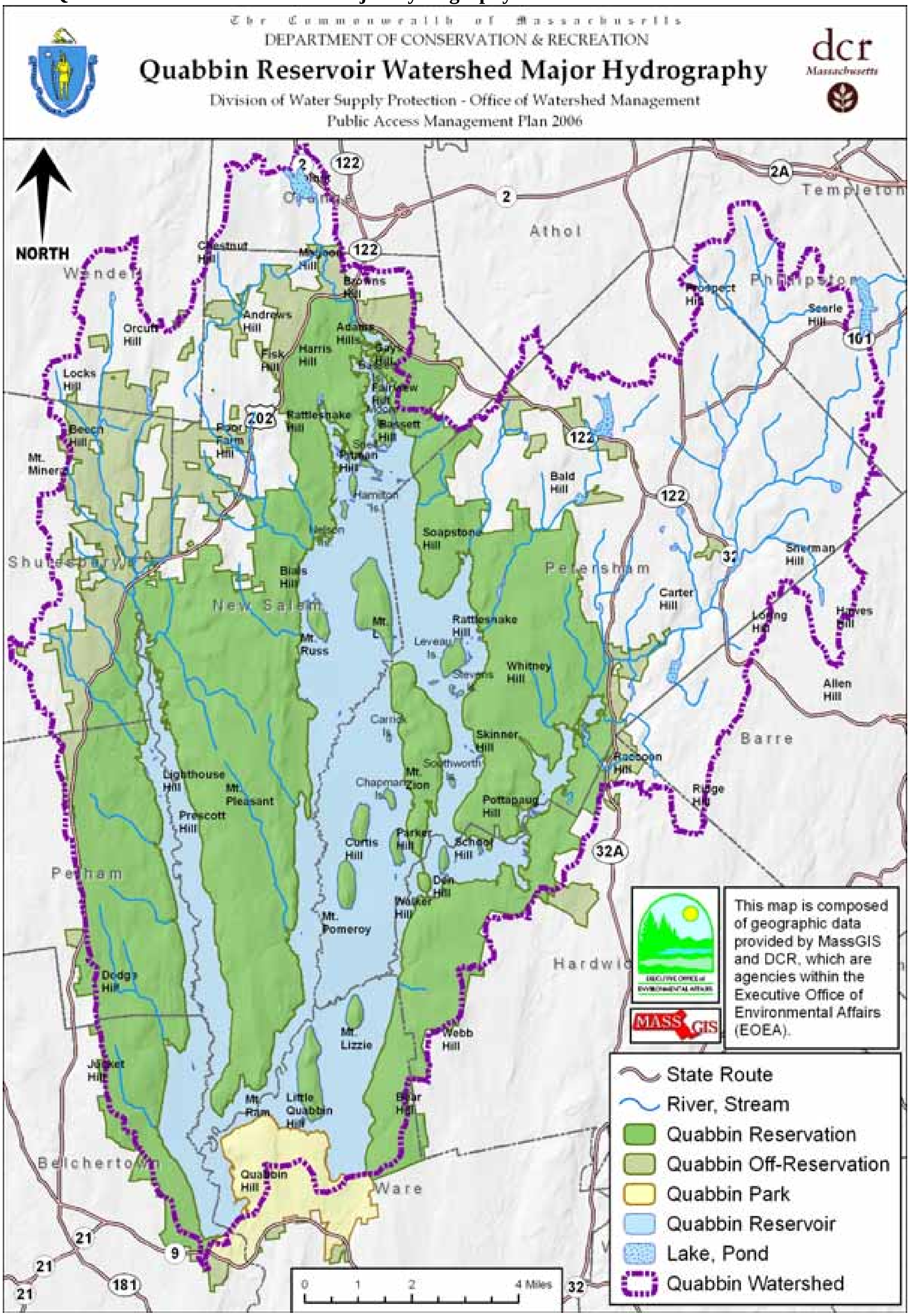
Figure 4: Chicopee River Drainage Basin and Quabbin Reservoir



2.3.1.2 Watershed

The 187 square mile watershed of the Quabbin Reservoir encompasses the lands and waters upstream from Winsor Dam, the terminal point of the reservoir. This reservoir and its watershed are also the major component of the watershed of the Swift River, which continues below the Quabbin Reservoir until the point at which it enters the Chicopee River. **Figure 5** shows the major hydrographic features of the Quabbin watershed.

Figure 5: Quabbin Reservoir Watershed Major Hydrography



2.3.1.3 Subwatersheds

59 subwatersheds have been identified within the Quabbin Reservoir watershed (**Figure 6)**, including the Cadwell Creek subwatershed depicted in **Figure 7**. These subwatersheds generally include the land and waters drained by tributaries from the point at which these enter the reservoir. Most of these are third order or higher tributaries.

Figure 6: Subwatersheds of Quabbin Reservoir Watershed

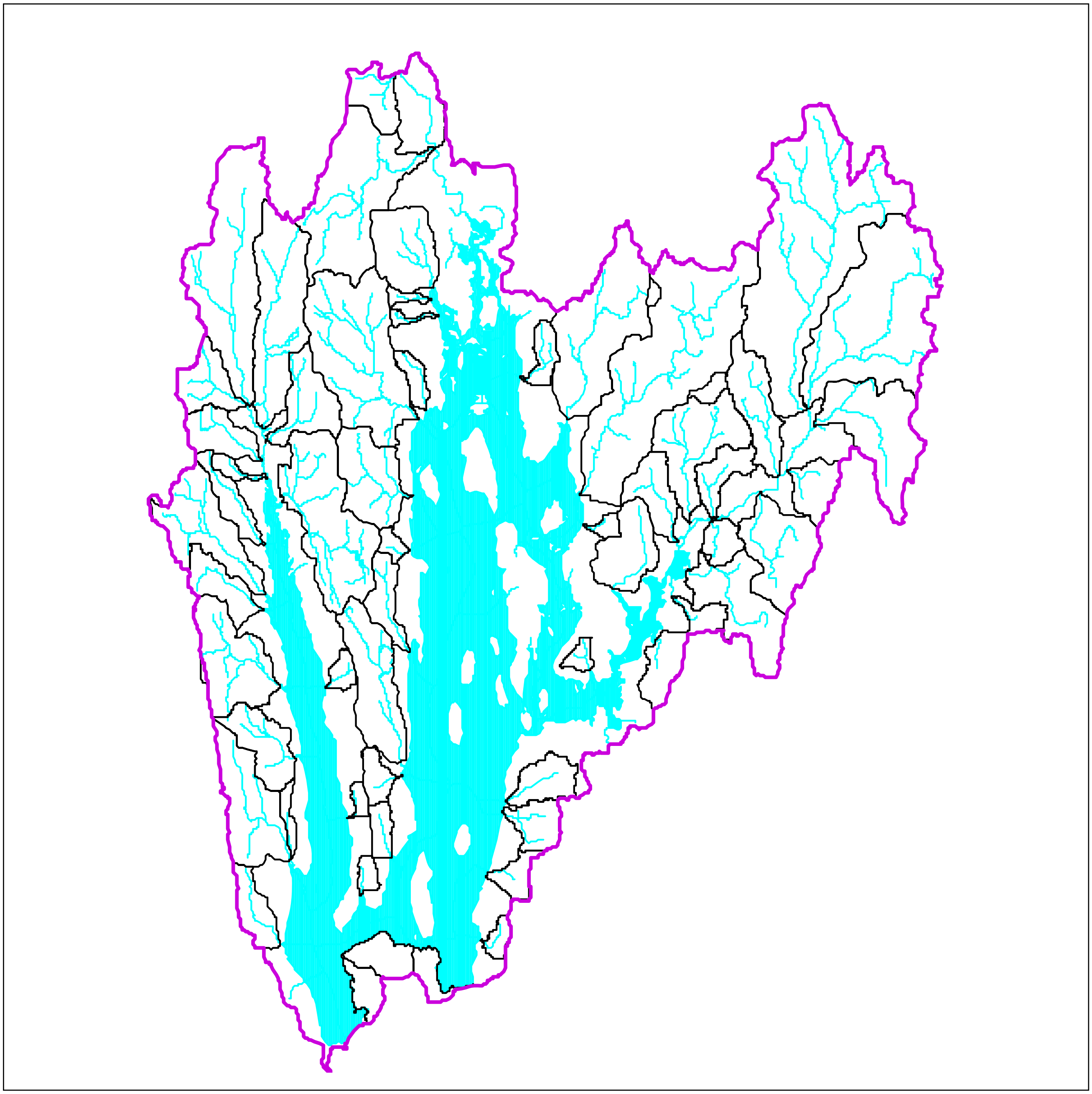
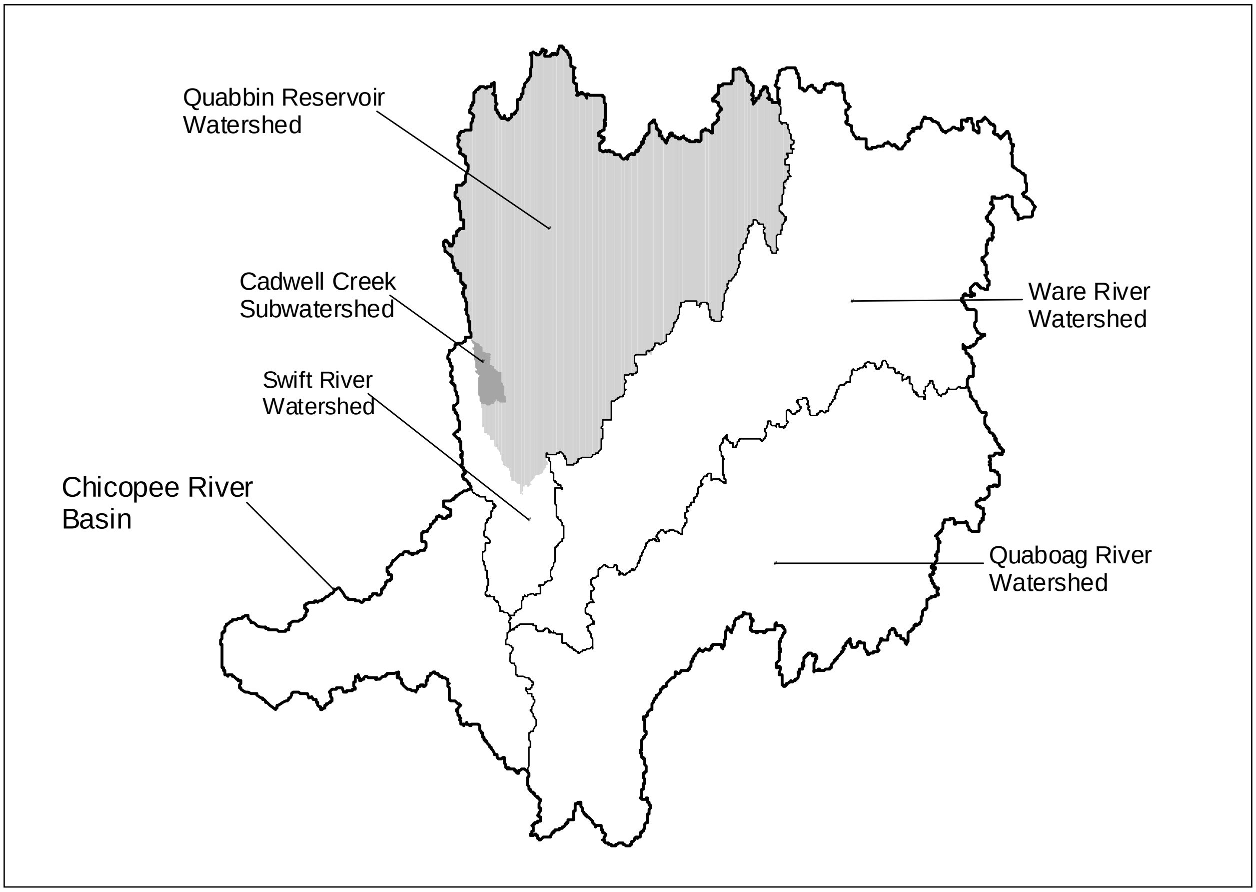


Figure 7: Quabbin Reservoir Watershed Hierarchy



2.3.1.4 Catchments

While catchments are not regularly used to guide management, they generally refer to areas that encompass the lands and waters that drain first or second order tributaries within the watershed.

2.3.2 Topography

The Quabbin Reservoir is located on the west flank of the eastern upland of south-central Massachusetts, an area characterized by extensive preglacial erosion and weathering followed by two major continental glaciations during the Pleistocene Epoch. The topography of the eastern part of the Quabbin watershed is irregular with moderate slopes, while the western part is characterized by two well defined, steeply sloped ranges oriented north and south through the length of the watershed. Elevation of the watershed ranges from 530 feet above mean sea level (reservoir's full pool elevation) to 1,383 feet above mean sea level, the elevation of Prospect Hill in Philipston, the tallest hill on the watershed. The topography is characterized by north and northeast trending hills and relatively narrow valley bottoms.

Excluding the reservoir surface, the land within the Quabbin Reservoir watershed falls within four broad slope classes, as detailed in **Table 13**.

Table 13: Acres of Quabbin Reservoir Watershed by Slope Class

Slope Class	Acreage	Percent of total
0-7.00%	34,270	36%
7.01-20.00%	48,123	51%
20.01-30.00%	8,760	9%
>30.00%	4,202	4%
TOTAL	**95,355**	

2.3.3 Geology

2.3.3.1 Regional Bedrock Geology

Note: this section was written by Peter Robinson, former Engineering Geologist for the MDC Water Division, for the 1986 MDC publication, "A Ten-Year Forest and Wildlife Management Plan for the Quabbin Watershed", pages 7-10.

The bedrock geology of the Quabbin Reservoir area is complicated, but in general, the rocks are complexly folded, medium to high-grade crystalline metamorphics in places intruded by granitic rocks. The rocks of the Quabbin region can be divided into four major groups.

1. The Pelham dome consists of a core of layered granitic gneisses with minor amounts of interbedded quartzite, schist, and amphibolite. In addition there are gray plagioclase gneisses similar to the Monson Gneiss around the margin rimming the core of the dome. The Pelham dome is located west of Quabbin. DCR/DWSP land holdings intersect the Pelham dome only in Pelham, Belchertown, and Shutesbury. The granite gneisses of the core are the oldest rocks in the area, on the order of 600 million years in age. The gray plagioclase gneisses are probably equivalent to the Monson Gneiss described below.
2. The Monson Gneiss is a gray, plagioclase-feldspar gneiss. It is variable, consisting of: a) layered gneiss without interbedded amphibolite; b) layered gneiss with interbedded amphibolite; c) massive (non-layered) gray gneiss; and d) minor amounts of other rocks. The layered gneiss may be of volcanic derivation whereas the massive portions may have been intrusive. The Monson Gneiss is of probably Early Ordovician age (450-500 million years ago). The Monson Gneiss underlies most of the low-lying land of the Swift River valley. The Monson Gneiss has been highly susceptible to erosion for reasons that are not fully understood. It is this erodibility that accounts for the broad expanse of the Swift River valley, a factor in its selection as a reservoir site. The rocks of the Pelham dome and the Monson Gneiss are now exposed in large dome-like structures, the tops of which have been truncated by erosion. These "domes" protrude up through the overlying rocks described immediately below.
3. The mantle sequence is so called because it structurally mantled the rocks of the Pelham dome and the Monson Gneiss prior to its removal from across the tops of the domes by erosion. The mantle sequence now occurs only where it has been preserved in the troughs between the domes. The mantle sequence consists of several formations, as follows:
    a. Ammonoosuc Volcanics – primarily layered volcanics of Middle Ordovician age (450 +/- million years ago).
    b. Partridge Formation – 430 to 450 million years ago consisting mostly of rusty-weathering sulfidic mica schist with interbedded amphibolites, also Middle Ordovician.

c. Fitch and Clough Formations – the Fitch Formation, of very minor occurrence, consists of calcareous granulites, traces of marble, and minor sulfidic schist. The Clough Formation consists of quartzite, stretched quartz pebble conglomerate, and minor schist. These formations are of Silurian age, 400 to 430 million years ago.

d. The Littleton Formation – mostly gray graphitic mica schist and minor quartzite of Early Devonian age, something less than 430 million years ago.

e. Erving Formation – mostly amphibolite and granulites, also of Early Devonian age.

4. Intrusive rocks of the region include the Hardwick Granite, the Belchertown Intrusive Complex, and the Prescott Complex. The Belchertown and Prescott complexes are more mafic than the Hardwick Granite, with a greater amount of iron and magnesium-bearing minerals, and also a feldspar content richer in calcium. This may affect the soil chemistry in these regions.

   a. The Hardwick Granite is a mass of granitic rocks of variable composition which range from granite to quartz diorite. The Kissman quartz non-zonite is also included. The rock contains distinctive large and elongate feldspar crystals.

   b. The Belchertown Intrusive Complex consists of massive biotite and/or hornblende quartz diorite and granodiorite. Only the very southwestern-most portion of the DCR/DWSP landholdings are on the Belchertown complex.

   c. The Prescott Complex occupying much of the Prescott Peninsula, is composed of gabbro, quartz diorite, and other related rocks.

The rocks at Quabbin have been affected by a series of tectonic events, the most recent of which occurred during the Acadian orogeny in the Early Devonian, about 380 million years ago. After initial folding of the rocks, the older and underlying gneiss now comprising the Pelham dome and the Monson Gneiss rose in huge bubble-like masses forming the gneiss domes. The overlying mantle sequence became draped over the rising gneisses and caught in the troughs between the domes. The intrusive rocks probably came in during this orogeny. Foliation in the intrusive rocks, however, suggests that intrusion occurred before the end of the orogenic events with the Hardwick Granite occurring somewhat earlier than the Belchertown and Prescott Complexes. Erosion subsequent to the orogenic events of the Early Devonian has removed thousands (perhaps as much as a few tens of thousands) of feet from the mountains formed at the time, now exposing the deep roots. Erosion, at its present level, has beveled the tops of the gneiss domes so that the mantle sequence is now preserved only in the downfolds between the domes. The domes are now surrounded by the mantle sequence rocks.

2.3.3.2 Surficial Geology

Much of the shape of the current Quabbin landscape was formed during the late Wisconsin glaciation when the Laurentide Ice Sheet spread south from Canada across New England approximately 25,000 years ago and then finally receded approximately 12,000 to 14,000 years ago (Whitney, 1994). The two-mile thick glacier impacted local topography and soils in a wide variety of ways, smoothing the landscape and leaving a cover of till, glaciofluvial deposits (material moved by glaciers and subsequently sorted and deposited by streams flowing from the melting ice; these deposits are stratified and may occur in the form of outwash plains, deltas, kames, eskers, and kame terraces) and glaciolacustrine deposits (sand, silt and clay deposited on the bottom of huge temporary lakes that formed when melting glacial ice was blocked by a combination of underlying bedrock and deposits) (Whitney, 1994). Sand, silt and clay remain suspended in fast-moving river water, but in slow-moving water such as lakes these fine materials are deposited.

Most of the uplands in the Quabbin Reservoir watershed and Ware River watershed are covered with glacial till deposits several feet to tens of feet deep, although there are significant differences in deposits and topography in the Swift River versus the Fever Brook basins (Rittmaster and Shanley, 1995). Gravel till is the most extensive glacial deposit in the Quabbin Reservoir watershed. Lowlands and valleys are usually filled with stratified glaciofluvial outwash deposits of silt, sand and gravel, and occasionally with swamp deposits of muck and peat. Depth to bedrock is variable; bedrock outcrops are commonly observed on the top and sides of hills, but bedrock may also lie much deeper beneath surficial valley deposits.

2.3.4 Soils

Soils are an important functional component of the forest biofilter, and management on the Quabbin watershed protection forest works to promote, preserve and maintain soil quality and health. Soil quality is the capacity of a soil to function, and healthy soil is able to perform at least the following five essential functions (http://soils.usda.gov/sqi/concepts/concepts.html):

- Regulates water by holding, storing and releasing rainwater and snowmelt.
- Sustains plant and animal life and enhances biodiversity.
- Filters potential pollutants by immobilizing and detoxifying organic and inorganic materials.
- Cycles nutrients such as carbon, nitrogen and phosphorous.
- Supports structures such as roads, buildings and cultural resources.

For the purposes of watershed management, Quabbin soils have been grouped by depth and drainage characteristics into the following five classes, based on USDA NRCS soil series descriptions (**Table 14**). These groupings provide a general framework for management considerations such as site quality, species composition, equipment operability and BMP requirements, ensuring the maintenance of soil quality and sustained soil function. Specific capabilities and limitations for each soil series are detailed in the USDA NRCS Soil Survey.

1. **Excessively drained soils.** Excessively drained soils are usually very coarse textured, rocky or shallow. Water is removed from the soil very rapidly. These soils are thick loamy sands occurring primarily on glacial outwash. The principal soils occurring most frequently in these areas are the Hinckley, Merrimac, Windsor, Carver, and Suncook series. These are relatively deep soils (>65”) and occupy 80% of the excessively drained area. Inclusions* of the Deerfield and Sudbury series occupy the remaining 20% of the area and are located usually in the lower landscape positions. They are moderately well-drained fine sandy loams, usually very deep and very stony.

2. **Well drained thin soils.** These soils are commonly of medium texture. Water is removed from the soil fairly rapidly, but is available to plants during most of the growing season. The principal soils occurring in these areas are the Shapleigh series, which are shallow soils (1”-24”) formed in glacial till located on the sides and lower slopes of hills and ridges. The other major series is the Charlton-Hollis-Rock outcrop complex occurring in similar landscape positions. This complex consists of 45% deep Charlton soils, 10% shallow Hollis soils, 10% rock outcrops, and 35% other soils. These other soils, listed as inclusions, are Paxton soils, which are located on hills and knolls, Ridgebury and Woodbridge soils, which are located on the lower landscape positions, and Brookfield and Brimfield soils, which are located in the transition areas.

* Because of the scale used in mapping, small areas (generally less than 5 acres) are not shown separately on soil maps. These small areas are known as inclusions.

3. Well drained thick soils. These thick (24”-65”) soils are formed in loamy and sandy glacial till on uplands. The Canton, Gloucester, and Charlton series are found generally on the lower sides of hills and ridges. Various inclusions of Hollis, Ridgebury, Montauk, Woodbridge, Scituate, Essex, Paxton, and Brookfield series may be found at any given location. The Paxton, Essex, and Montauk series can generally be found on the tops and upper parts of hills and ridges. Inclusions of Brookfield, Canton, Brimfield, Charlton, Woodbridge, Ridgebury, Scituate, and Gloucester series may be found scattered throughout the upper portion of the landscape.

4. Moderately well drained soils. Moderately well drained soils are wet for only a short period during the growing season but the removal of water is somewhat slow during these times. These soils consist of very deep, (to 65” and greater) fine sandy loams. The Sudbury and Deerfield series are formed on outwash plains and terraces and occupy nearly level positions on the landscape. Other soil inclusions found within these types have been identified as the Merrimac, Walpole, Scarboro, Hinckley, and Windsor series. The Woodbridge series are formed on glacial till on uplands and are generally found on the tops of upper parts of hills and ridges. Inclusions of Charlton, Paxton, Canton, Montauk, and Ridgebury may occur within the Woodbridge series. The Scituate soil series, formed in glacial till on the uplands, is commonly found on the lower slopes of hills and ridges. Inclusions within this type are the Montauk, Canton, Woodbridge, Paxton, Ridgebury, and Walpole.

5. Poorly to very poorly drained soils. Poor drainage usually results from a high water table where water is removed so slowly that the soil is saturated or remains wet for long periods during the growing season. These soils are very deep, extending to a depth of 50” or more, and consist of fine sandy loams and mucks. The Ridgebury and Whitman series are found in depressions and in low areas on uplands. Inclusions of Woodbridge, Paxton, Scituate, and Swansea series comprise about 20% of these soils. Freetown and Swansea mucks are organic soils formed in depressions and on plain areas. These types can also contain about 20% included soils such as the Whitman, Scarboro, Ridgebury, and Walpole series. The Scarboro-Rippowam complex and the Walpole series occur in depressions and along drainage ways. The complex includes about 40% Scarboro, 30% Rippowam, and 30% other soils, while the Walpole has approximately 20% included soils from the Sudbury, Deerfield, and Swansea series.

Table 14: Acres of Composite Soil Type by Block[1]

Block	Excessively-Drained Soils	Well-Drained Thin Soils	Well-Drained Thick Soils	Moderately Well-Drained Soils	Poorly to Very Poorly-Drained Soils
Hardwick	1,548	4,017	3,469	2,283	837
Pelham	429	3,909	3,623	2,385	707
New Salem	2,334	2,705	3,609	1,145	1,186
Prescott	612	6,294	2,619	1,716	896
Petersham	862	2,374	2,065	3,620	972
Total	**5,785**	**19,299**	**15,385**	**11,149**	**4,598**
Percent of Watershed	10.3	34.3	27.4	19.8	8.1

[1]For management purposes, the Quabbin holdings are divided into 5 large regions or “blocks”, named after the local town

Generally, the soil within the Quabbin Reservoir watershed supports a wide variety of native tree species, most notably northern red oak, eastern white pine, red maple, sugar maple, and white ash. The dominant forest cover is oak with red maple occurring on the wetter sites and white pine dominating the drier sands and gravel (while white pine grows vigorously on moist soils, it competes poorly with other species on these sites during the establishment phase of the stand). Sugar maple and white ash are generally limited to less acidic soils with moderately high moisture content.

2.3.5 Hydrology and Climate

2.3.5.1 Precipitation and Evaporation

Annual precipitation on the Quabbin Reservoir watershed since 1930 has averaged 46.38 inches per year, with a range between a low of 29.7 inches in 1965 and a high of 66.4 inches in 1938 (**Table 15**). Historically (1930 to 1979), September has been the wettest month, with an average of 4.11 and a maximum of 14.8 inches of precipitation, while February has been the driest month, with an average of 2.97 inches. Of the 46 inches of precipitation that fall directly on the 24,000 acre Reservoir surface, approximately 22 inches evaporate. Annual evapotranspiration (water lost through the combined effects of evaporation from the ground surface and transpiration from the vegetation) in central Massachusetts has been estimated between 22 and 28 inches (Thornthwaite et al., 1958). The average yield to the Reservoir from the entire watershed is approximately 50% of all precipitation. The Reservoir, at full elevation of 530 feet, contains 412 billion gallons within a shoreline that totals 181 miles in length.

The hydrology of the watershed is strongly influenced by the preponderance of forest cover. Forest cover has both positive and negative effects on water yield, with net yield the result of precipitation, evapotranspiration, interception, soil moisture and ground water storage. Watershed studies show that evapotranspiration losses from forests are significant, but highly variable, with water yield increases occurring when part or all of a forest cover is removed or replaced by herbaceous vegetation. The most significant yield differences among forest covers are between conifers and deciduous trees. (Note that the current Quabbin forest is approximately 2/3 deciduous and 1/3 conifer, primarily pine.) In general, forest canopy interception and evapotranspirational losses are greater for conifers than for deciduous species, although this varies with stocking and with storm characteristics (deciduous forests average 13% overall interception losses, while coniferous forests average 28%, (Dunne and Leopold 1978). The creation and maintenance of open land generally reduces interception and evapotranspiration losses and can result in a significant increase in yield.

2.3.5.2 Snow surveys

The Division has conducted a snow survey in the Quabbin Reservoir watershed since the 1930s. The purpose of the survey is to record the potential rise in reservoir elevation (potential inflow) as well as the flood potential of rivers and streams due to snowmelt. Prior to the filling of the Quabbin Reservoir, the Division monitored twelve snow survey stations in the Quabbin Reservoir watershed. Once the reservoir was filled, six of the twelve stations remained. DWSP staff currently monitors six snow survey stations weekly, typically between January and April, taking six samples at each station using a snow density gage to measure snow depth and weight. The average depth and weight measurements are used to determine the average water content of the snow pack. Staff report average depth and water conversion figures as both "potential rise in reservoir elevation" and as "river and stream flood potential". Over the past 22 years, the average annual snow depth at the six stations within the Quabbin Reservoir watershed has been 47.47 inches.

Table 15: Total Annual Precipitation Measured at Belchertown Station

Year	Annual Total Precipitation		Year	Annual Total Precipitation
1930	39.36”		1969	44.58
1931	45.30		1970	41.95
1932	41.43		1971	44.58
1933	53.48		1972	57.88
1934	49.64		1973	50.24
1935	38.15		1974	49.43
1936	55.24		1975	58.98
1937	55.71		1976	46.19
1938	66.41 **(max.)**		1977	52.01
1939	38.37		1978	43.55
1940	40.48		1979	58.59
1941	32.66		1980	32.41
1942	47.55		1981	42.99
1943	43.99		1982	48.09
1944	42.40		1983	57.41
1945	50.71		1984	49.92
1946	38.43		1985	45.93
1947	39.42		1986	44.2
1948	45.25		1987	40.38
1949	37.40		1988	43.42
1950	41.30		1989	58.02
1951	49.73		1990	53.10
1952	45.19		1991	51.72
1953	51.52		1992	41.63
1954	49.03		1993	43.5
1955	64.92		1994	50.85
1956	46.57		1995	44.98
1957	36.32		1996	60.43
1958	49.47		1997	43.8
1959	54.25		1998	43.38
1960	50.57		1999	48.11
1961	41.75		2000	52.97
1962	38.14		2001	39.87
1963	41.64		2002	44.36
1964	31.57		2003	54.03
1965	29.7 **(min.)**		2004	42.15
1966	36.66”		2005	54.38
1967	44.89		2006	44.18
1968	40.47		**Average**	**46.35**

2.3.5.3 Streamflow

The Quabbin Reservoir drains a land area totaling approximately 150 square miles (~96,000 acres). In order of size, the most important subwatershed drainages include the East Branch of the Swift River (43.7 sq.mi.), the West Branch of the Swift River (12.4 sq.mi.), the Middle Branch of the Swift River (10.7 sq.mi.), the East Branch of Fever Brook (8.7 sq.mi.), Hop Brook (5.4 sq.mi.), the West Branch of Fever Brook (4.5 sq.mi.), and Dickey Brook (4.3 sq.mi.) (**Figure 6**). The Ware River watershed, upstream from Shaft 8, is a major tributary to the Reservoir during high flow winter periods when diversion may occur. Within the portion of the watershed owned by DCR, there are approximately 132 miles of streams, excluding intermittent streams, and 2,272 acres of wetlands, including year-round water bodies, but excluding vernal pools.

Stream flow in the Quabbin Reservoir watershed, as in most of New England, has significant seasonal variations. Flows tend to be highest in the spring, due to snowmelt and high groundwater; and lower in the summer and early fall due to greater solar radiation and evapotranspiration. These seasonal changes are important since “high flow” water quality threats (e.g., streambank erosion) tend to occur in the spring, whereas “low flow” water quality threats (e.g., higher bacteria levels resulting from lower dilution) tend to occur in the summer and early fall. DCR staff monitors stream flow at selected sites where Quabbin water quality samples are taken. Sample data on stream flow are shown in **Table 16.**

Table 16: Streamflow Data for Selected Tributaries of the Quabbin Reservoir

	1996 Data (cfs = cubic feet per second)				
Station Name (number)	**Drainage Area (miles^2)**	**Mean Daily Discharge Rate (cfs)**	**Maximum Daily Discharge Rate (cfs)**	**Minimum Daily Discharge Rate (cfs)**	**Total Annual Discharge**
East Branch Swift River Near Hardwick, MA (01174500)	43.7	135	985	9.8	4.3 billion cf (31.8 billion gals)
West Branch Swift River Near Shutesbury, MA (01174565)	12.6	37.5	377	1.2	1.2 billion cf (8.8 billion gals)
Cadwell Creek Near Belchertown, MA (01174900)	2.55	8.86	80	0.21	0.3 billion cf (2.1 billion gals)

Source: USGS-MA, 2000

2.3.6 Developed DWSP Lands at Quabbin

2.3.6.1 Administrative Areas

2.3.6.1.1 Administrative Buildings

The Quabbin Administration Building, located in Quabbin Park, was built between 1938 and 1939. The Visitor Center and many of the professional staff offices and meeting areas are located in this building. The Quabbin Visitor Center was opened in 1984 to meet the growing demand for visitor information services (surveys have recorded in excess of 500,000 visitors annually). The Quabbin Administration Building also houses State Police offices and the separate garages used for storage and mechanical maintenance/repair. The historic seaplane hanger beneath the Administration Building houses equipment and carpentry and sign-painting shops. There are also a Forestry/Natural Resources office and the

Ranger's Headquarters in the Quabbin Park, as well as a stock room for tools, supplies and an adjacent welding and metalworking shop. In addition to the administrative buildings at the southern end of the Reservoir, there is a Forestry field office and a heavy equipment garage complex at the northern end, off Route 202 in North New Salem.

2.3.6.1.2 Quabbin Hill Lookout Tower

The Quabbin Hill Lookout Tower was built from 1940-1941. The tower is 84 feet high. On a clear day, in addition to the Reservoir itself, a visitor can see portions of Massachusetts, New Hampshire, and Connecticut from the tower.

2.3.6.2 Boat Launch Sites

There are three boat launch sites on the Reservoir for boat fishing in designated areas: Area 1: Gate 8 off Route 202 in Pelham; Area 2: Gate 31 off Route 122 in New Salem; and Area 3: Gate 43 off Route 32A in Hardwick, MA. These areas include field offices for staff, parking areas for vehicles and boat trailers, launching docks, and sanitary facilities.

2.3.6.3 Powerline Rights of Way

Powerline rights-of-way cover 289 acres within DWSP holdings surrounding Quabbin Reservoir and include three major lines:

1. An overhead powerline entering DWSP property near Gate 9 in Pelham and running SE to and then parallel to the shoreline toward the DWSP Administration Building in Quabbin Park (E5/F6 line), then easterly through the Park, exiting just beyond Peppers Mill Pond (B-69 line).
2. An underground cable line that crosses DWSP boundaries several times within the towns of Shutesbury and New Salem, running northeasterly and crossing Route 202 into the Quabbin Reservation north of Giles Brook, then leaving DWSP property north of North Spectacle Pond.
3. An overhead powerline that enters DWSP property in New Salem, north of Gate 28, runs southeasterly across the northern tip of the Reservoir, through DWSP properties in Petersham, and then leaves DWSP property between Gate 40 and Carter Pond, in Petersham (E205E line).

2.3.6.4 Quabbin Park Cemetery

The Quabbin Park Cemetery was built between 1931 and 1932. During that time, 6,601 remains were transferred. The Cemetery is 82 acres in total size, including 22 developed acres.

2.3.6.5 Fields and Other Non-Forest Areas

There are 88 acres of lawns and ornamental plantings at Quabbin, as well as 154 acres of administrative areas, 311 acres of fields with grass and herbaceous cover, 111 acres of upland brush, 8 acres of abandoned orchards, and approximately 20 acres of active gravel pits.

2.4 Quabbin Forest Conditions

2.4.1 Forest History

2.4.1.1 Paleoenvironments

The following is quoted from a September 1990 report by the Cultural Resource Group of Louis Berger & Associates, Inc. It is included here for general information on post-glacial development of the landscape, and to provide a context for prehistoric cultural resources protection.

> Prior to prehistoric man's entry into central Massachusetts, glaciers had scoured the landscape. Glacial Lake Nashua occupied the approximate position of the Wachusett Reservoir and another, Lake Hitchcock, was located from 10 to 15 miles west of Quabbin. The lakes were apparently gone or recently drained as prehistoric Native Americans began to populate the area.
>
> Forests of this early time are characterized as spruce parkland and spruce woodland with admixtures of some deciduous elements creating a species mosaic that has no modern analog (Curran and Dincauze 1977). Excessively drained glacial landforms would have been attractive to both man and animal during this time of cooler and wetter climate. The biological carrying capacity of area forests would have been less than that of modern habitats in the same area but greater than what can be ascribed to modern conifer-dominated forests.
>
> Bogs, marshes, and ponds probably characterized many lowland environments as they do today. The effects of beaver populations on these lowland environments during prehistoric times cannot be accurately evaluated. Beaver are responsible for many of the modern wetland features. The types of vegetation associated with them, however, would have been substantially different. Nonetheless, we can assume that these features would have been game-attracting habitats. Extinct and more northern-adapted animal species would have existed in the area including mastodon and caribou. Now-extinct drainage patterns were probably viable low order streams. The velocity of streams in general was probably great as they handled glacial meltwater.
>
> As regional climates began warming circa 8,000 BC, the spruce woodland was eventually replaced by a conifer-deciduous forest in which pine was heavily represented (Dincauze and Mulholland 1977). No dramatic changes in the biological carrying capacity of the project region are postulated although northern animal species were likely being supplanted by species more common to the area today. Streams were undoubtedly prolific, even in comparison with the well-watered settings of the present time.
>
> Climates circa 6,000 BC and 1,000 BC are viewed as radically oscillating with warm temperatures and decreased rainfall being the overall trend. Windblown soils found in Central Massachusetts and the Middle Connecticut River Valley (Johnson and Stachiw 1985; Johnson and Mahlstedt 1984; Dincauze et al., 1976) may be an indirect result of this period referred to as the Thermal Maximum. Pine-oak forests give way by 4,000 BC to a temperate deciduous forest characterized by oak and hemlock. These new plant communities, together with adapted animal species, would have dramatically increased the carrying capacity of local environments and the range and density of resources that could be exploited by humans.

> Although many upland and low order streams may have become intermittent or extinct at this time, the quality of upland and lowland environments was dramatically increased. Seasonal changes were probably first pronounced during this period in terms of the fluctuating productivity of biological resources exploited by man. At the same time, decreasing rates of sea level rise would have helped to stabilize anadromous fish populations and regularize their appearance in local areas. Climatic shifts circa 1,000 BC and later are viewed as minor and resulted in no major alterations of regional environments. The quality of environments in Division watershed areas was essentially modern by 1,000 BC if not earlier.

2.4.1.2 Land Use and Disturbance History

The current New England forest carries the imprint of changes ranging from major climatic shifts thousands of years ago to the abandonment (and successional reclamation) of agricultural land within the past 150 years. The relative role of the range of disturbances visiting this forest has long been the subject of heated debate. Following is a brief review of some components of this debate.

2.4.1.2.1 Prior to European Settlement

There is considerable uncertainty as to what the actual pre-colonial forest was like in the Quabbin region. Overall species composition in this early New England forest was likely similar to the present day with the exception of species since extirpated, like chestnut, or imported from other areas, like red pine. The distribution of size-classes of the pre-colonial forest would have been influenced greatly by the length of time since the last major weather disturbance, especially hurricanes, and the severity and magnitude of previous fires or of Native American land use practices. Hurricanes disturb New England frequently, with catastrophic storms arriving, on average, every 100-150 years. Fires occurred naturally in the pre-colonial forest, but may have also been set by the Native American populations for a variety of reasons, including facilitation of hunting and clearing for agriculture.

Bromley (1935) and Day (1953) felt that the population of Native Americans in pre-Colonial times was sufficient to burn large areas of forest frequently and that burning was a universal custom to keep forests open and to produce browse for wildlife. Bromley also points out that in some cases deer modified the forest locally. He notes that larger trees occurred mainly in wetter woods, and that oak and pine forests were usually subjected to annual burnings, while beech and maple were commonly too wet to burn. The prevalence of oak in the original forest is likely in part due to the long history of regular but infrequent fire (Bromley (1935) and Russell (1983)). Some ecologists feel the impact of fires was great enough to have increased the oak-chestnut forest type significantly and effectively caused it to replace the northern hardwoods forest in interior sections of New England.

The fact that turkey, deer, and ruffed grouse flourished indicates an environment with edge. The decline of quail, which occurred in pre-settlement times, also indicates that regrowth of forest and fire suppression in modern times negatively impacted some species (Thompson and Smith, 1970). Thompson and Smith (1970) suggest that the demise of the heath hen (which disappeared from Massachusetts in 1840) was probably due to fire suppression after settlement, and that, in general, fire has been a key factor in the past abundance and distribution of New England wildlife.

Whatever their cause, disturbances likely maintained a diversity of ages, sizes, and species in the early Quabbin forest. While stands of mature, mid to late successional species of great size are in the historical record, the pre-colonial Quabbin landscape was likely a patchwork of varying composition, given the record of disturbance (Cronon, 1983). However, this mosaic, wrought by a variety of randomly patterned disturbances, was forced into a simpler pattern by the arrival of the colonists, a population bent on agricultural development.

2.4.1.2.2 Colonial Settlement

By the close of the 18th century, colonists had eliminated almost all of the "original" New England forest (Carroll, 1973). At the peak of colonial development around 1850, greater than 75% of the Massachusetts forest had been cleared (Russell, 1976, p.527), leaving only the steep and rocky sites and wetlands in tree cover. Land had been initially cleared for general agriculture, followed by a large expansion of clearings to support the rearing of sheep. The forest supplied building material for homes and barns, fuel for cooking and heating, charcoal, and other forest products that provided income. Excess wood was simply piled and burned to complete agricultural clearings.

Although the task of clearing the original forest with hand tools was formidable, it pales in comparison with the energy expended to wrestle stone from the ground and use it to build fences and foundations. To link the fields and farms of this era, the roads followed the topography and consequently are often narrow, winding and steep. Gravel was not used in abundance for road surfaces and when additional fill was required it was usually dug from roadside banks.

The clearing of land for agriculture was to some extent ordered by a perception of soil/tree cover relationships:

> Trees that required and maintained moist forest conditions, such as hickories, maples, ashes, and beeches, generally produced rich black humus beneath their fallen leaves, and settlers interpreted them as indicators of prime agricultural land. Oaks and chestnuts, with their denser undergrowth and more frequent groundfires, had thinner soils which required more work before they would produce favorable European crops. Still less desirable were the acidic and often sandy soils beneath various conifers - moist under hemlocks and spruces, dry under pitch and white pines - and colonial farmers avoided these wherever they could. (Cronon, 1983)

While these observations may have directed the colonists to first clear the most productive soils, ultimately 75% of the central New England forest was cleared for some type of agriculture (Marchand, 1987). In addition, the colonists took advantage of rich wetland soils by ditching and draining them and using these moist soils for hay, cranberries and in some cases for crops (Russell, 1976).

2.4.1.2.3 Agricultural Abandonment

As more and better land was open for settlement further west and as New England's hill farms became unproductive, marginal agricultural lands were abandoned. During the period between 1830 and 1865 farm land abandonment in New England occurred at an unprecedented pace, exacerbated by the Civil War's recruitment of young farmers from the region and by industrialization (Marchand, 1987). For example, the Town of Petersham was estimated to be 15% forested in 1865, 48% in 1895, 55% in 1905 and 85% in 1976 (Patric and Gould, 1976). The Quabbin forest, which was likely also as much as 75% cleared land during the height of colonial agricultural development, would ultimately return to nearly 100% forest cover within 100 years time.

Much of this abandoned farmland would not be reclaimed by the same species composition which fills holes in a disturbed forest. Many of the abandoned fields had last been used either as pasture or to produce dwindling yields of hay, and so were in dense grass cover at the point of abandonment. This fact accounts for the emergence of white pine as a dominant forest type during the successional reclamation of these abandoned farms (Marchand, 1987). White pine and other conifers such as red cedar are better able to invade and repopulate these grasslands than other species because their heavy seed can penetrate grass to make contact with the soil and their drought tolerance enables them to survive dry summers, even with competition from dense grass roots for available moisture. Fields that were tilled right up to the time of their abandonment would have immediately supported a broader range of early-successional species than those that were grasslands at the time of abandonment.

Early in the 20th century, as the white pine crop grew to merchantable size, the value of the standing pine trees increased dramatically (Marchand, 1987). A lumber boom, aided by the steam- powered portable sawmill, resulted in the logging of 15 billion board feet of primarily white pine lumber from the central New England region between 1895 and 1925. The trees were cut by hand, drawn out of the forest by horse, mule or oxen, and milled on site. The sawn lumber was used for boxes, buckets, matches and building materials. This market could use a variety of lumber grades and therefore both high and low quality stands were in demand.

The heavy cutting of white pine at the turn of the century favored regeneration by understory species that had established a tap root and thus could sprout vigorously after a disturbance, such as the oaks, hickories and chestnuts (Marchand, 1987). Most other species were less likely to persist following the intense logging activity and by the fires that followed in the dry slash of the old-field pine cutting. White birch seeded in after fire and became a component along with other birches and maples, but oaks eventually dominated the shorter-lived birches and maples. Similar to the conditions that preceded the establishment of white pine on abandoned farms, the heavy cutting and burning that established Quabbin's large, contiguous oak stands is not likely to be repeated.

2.4.1.2.4 Chestnut Blight

American Chestnut was a valuable and abundant hardwood tree in this region. This fast growing tree was normally associated with oaks and hickories. Chestnuts produced frequent seed crops that were important to both humans (food and cash crop) and animals. The trees grew tall with straight grain and therefore worked and split well. The wood was valued for barn and house frames, furniture, doors, fence posts, railroad ties (due to its rot resistance) and many other uses.

The chestnut blight (*Endothia parasitica*) was introduced around 1904 and within two decades had killed most of the mature chestnut trees in New England (Spurr and Barnes, 1980, p.450). Chestnut had occupied a wide variety of sites and was a significant component of the forest. Because chestnut had so many uses and decayed slowly, most of the mortality was salvaged through extensive logging operations. The blight caused a thinning where chestnut was a major component and stimulated the growth of residual trees. As succession reclaimed the openings left by the dying chestnut, it was often simply replaced by its common associates in the stand and the oak-chestnut types were simplified to oak-hickory or oak types (Spurr and Barnes, 1980, p.450).

The full impact on the forest ecosystem from the loss of chestnut is difficult to determine because it influenced so much of that ecosystem. Clearly, it had been an important food supply for wildlife (as well as humans), a major component of the forest affecting both structural and species diversity, and a persistent competitor for light and space in the regenerative phase of forest development. The growth and development of the next forest has been different because of this loss. There is some hope that chestnut will make a comeback when the disease weakens or the tree becomes more resistant. Researchers are currently working to splice genetic codes that will build resistance in the American chestnut, providing perhaps the best hope for the return of this tree to its native woodlands. For more information, contact the American Chestnut Foundation at: http://www.acf.org .

2.4.1.2.5 The Hurricane of 1938

The Hurricane of 1938 was a 100-150 year event that seriously damaged approximately 15,000 acres of the Quabbin forest, primarily on the east, southeast and south aspects. Level sites, northeast aspects and the upper slopes of north and northwest aspects were also damaged, though less severely. Across the watershed, the impact varied tremendously from nearly complete damage in older pine stands, to scattered individuals in young hardwood stands. Trees downed or tipped by this storm are still evident in present day stands. Pine rots slowly and in some areas of blow down, it is still difficult to walk through hurricane-affected stands.

Aftermath of the 1938 Hurricane.

A great effort was made to salvage the blow-down and several million board feet of the most accessible and best quality timber were salvaged by the MDC on Quabbin lands. Approximately 20 million board feet of mature timber, primarily white pine, were tipped, snapped, or felled by the hurricane. Even though large crews were sent into the woods to lop damaged trees, the pine remained a potential fire hazard for many years. Fortunately, much of the Quabbin watershed in 1938 was in 10-40 year old hardwood tree cover from turn of the century farm abandonment or recently planted seedlings on open land purchased by MDC, so these areas were not seriously damaged by the hurricane.

1938 was reported to have been a heavy white pine seed year. The hurricane spread this seed great distances and many young pine seedlings became established in the understory on well-drained uplands. Other good pine sites, such as the kame terraces, also regenerated to white pine following damage to the pine overstory. Mature pine stands on moist till soils regenerated to oak, ash, maple, birch, hemlock and scattered pine following the hurricane, whereas immature stands without advance regeneration regenerated to light-seeded hardwood species such as birch and maple.

2.4.1.2.6 Gypsy Moth

The gypsy moth was introduced in Massachusetts in 1869, as a potential silk producer. This local introduction of a non-native insect has had a significant impact on the Quabbin forest because these insects prefer the leaves of oaks, the most common hardwood species on the watershed. The dominance of oak in this region has enabled gypsy moth caterpillars to defoliate significant areas of the DWSP properties during peak infestations, especially on drier hilltops. From these hill tops young caterpillars can be blown for many miles and result in widespread defoliation. Mortality from the gypsy moth extends beyond the canopy red oak to a developing understory of pine, the less vigorous white, black and chestnut oaks and the scattered hemlocks within oak forests. Serious defoliations

Adult Gypsy Moth.

have occurred in 1889, 1964, and 1981. The most recent defoliation of any size affected the majority of the Mount Pomeroy Island in 2000.

Chemicals have not successfully controlled gypsy moths defoliations in New England. More effective natural control is usually caused by a nucleopolyhedrosis virus (*Borralinivirus reprimens)* brought on through starvation in the later stages of defoliation in the second or third year of the cycle and by a fungus that was released approximately 70 years ago to control gypsy moths (*Entomophaga maimaiga*), which has now increased to levels that are devastating the caterpillars in early stages of their development, so long as certain humid conditions are present. Effective long-term control may also result from the diversification of the oak forest, especially on the well-drained upland sites.

The introduction of the gypsy moth has affected the growth and composition of the Quabbin forest. Mortality rates have been high in oaks and mixed-stand hemlocks in outbreak areas, and growth rates are greatly diminished during the years of defoliation for trees that survive. Advance understory regeneration of pine has been killed, representing many years of growth. Particularly susceptible trees such as white oak have been lost from large areas of mixed oak forest. It is unclear what the future of this impact will be, although it will likely depend to a large extent on the ability of natural defenses, perhaps including changes in species composition, to adapt to the presence of the gypsy moth. In areas where mortality from gypsy moth has been or will be significant, the importance of maintaining the regenerative capacity of the forest cannot be overemphasized.

2.4.1.2.7 Elimination of Access

Once gates and signs were put up around the Quabbin Reservoir in the 1940s, the public was initially denied further access. Prior to this time the public had used the Quabbin lands for fishing, hunting and trapping. The concurrent impacts from clearing 24,000 acres, burning several thousand acres, and blow-down by the hurricane of 1938 on 15,000 acres produced large amounts of deer browse. Coupled with hunting prohibition, this resulted in a large deer population that seriously impacted the forest understory from the 1940s until hunting resumed, following long and contentious debate, in 1991.

The only exception to prohibited public access in the late 1940s was for shore fishing. A strong sportsmen's lobby prevailed over MDC's official objections to the program. Once walking access was allowed for fishing (1946), public access for hiking gradually gained acceptance for all but the Prescott Peninsula, which remains reserved for research and management purposes. In recent years, as open spaces throughout Massachusetts become increasingly developed, the demand for recreational use of the DWSP watershed properties has increased and will likely continue to provide management challenges into the future.

2.4.1.2.8 Public Access Management Plans

The first Public Access Plan for the Quabbin Reservoir watershed was published in 1988. This plan outlined control policies and monitoring mechanisms used to mitigate possible negative impacts from public access to Watershed Management property in Barre, Belchertown, Hardwick, New Salem, Orange, Pelham, Petersham, Shutesbury, Ware, and Wendell. An update was completed ten years later in 1998. Another update was initiated in 2005, and was completed in spring 2006.

DCR and its predecessor have continuously involved stakeholders in its public access policy development, review, and modification. The planning process for this latest update included two public meetings, a visitor survey, an abutter's survey, and a public hearing. DCR continuously receives pressure to allow new recreational opportunities and increase the availability of currently allowed activities. The input received while updating the Quabbin Access Management Plan demonstrated, however, that local residents, land abutters, visitors, and environmental organizations are supportive of DCR's policies to protect the public water supply while allowing controlled access to these resources. **Figure 8** and **Table 17** provide a summary of the policies described in the 2006 *Public Access Management Plan Update: Quabbin Reservoir Watershed System.*

2.4.1.2.9 Primary Versus Secondary Forests

The vast majority of the current forest at Quabbin and across New England is the result of the return of the forest to lands that were cleared for agriculture following European settlement of the region. These forests are commonly referred to as 'secondary forests' or 'second growth'. However, over the course of post-settlement history, some woodlands within the region were not cleared to make way for agriculture. Primary forests, also referred to as "primitive woodlands" are areas that have, to the best of our knowledge, always been woods, and were never plowed or converted to pasture or hayfield. Henry David Thoreau discussed the concept of primitive woodlands as part of an overall forest classification system. Thoreau defined primitive woodlands as those that have always been forested, even though they may have been cut one or more times in the past to produce wood products. They are not to be confused with old growth, which are generally areas in which direct human manipulation has been mostly absent throughout history. The critical characteristic is that these woodlots were never used for agricultural purposes and that they therefore have always had a forest floor (Foster, D.R. 1999). There is increasing interest in these areas as reference areas for comparison to areas that were farmed, in an attempt to quantify the legacy effects of agriculture on soil and vegetation characteristics.

In an effort to identify primary forests, the Harvard Forest has gathered land use maps from 1830 that were produced by many towns in Massachusetts for tax purposes, and which identify woodlands present at that time. The assumption is that if an area had not been cleared for agriculture by 1830, it is likely that it was never cleared for this purpose as farm abandonment began in earnest shortly after this date. Landscape position also predicts these areas to the extent that very steep or very wet areas were not converted to agriculture. From these sites and using the 1830s maps, DWSP has identified areas totaling approximately 1,000 acres as potential primary woodlands. Through field checking, some of these potential areas have been removed from the designation because they were found to be bounded by stone walls, indicating that they were converted to agricultural uses at some point in the past.

Figure 8: Quabbin Reservoir Watershed Public Access Map

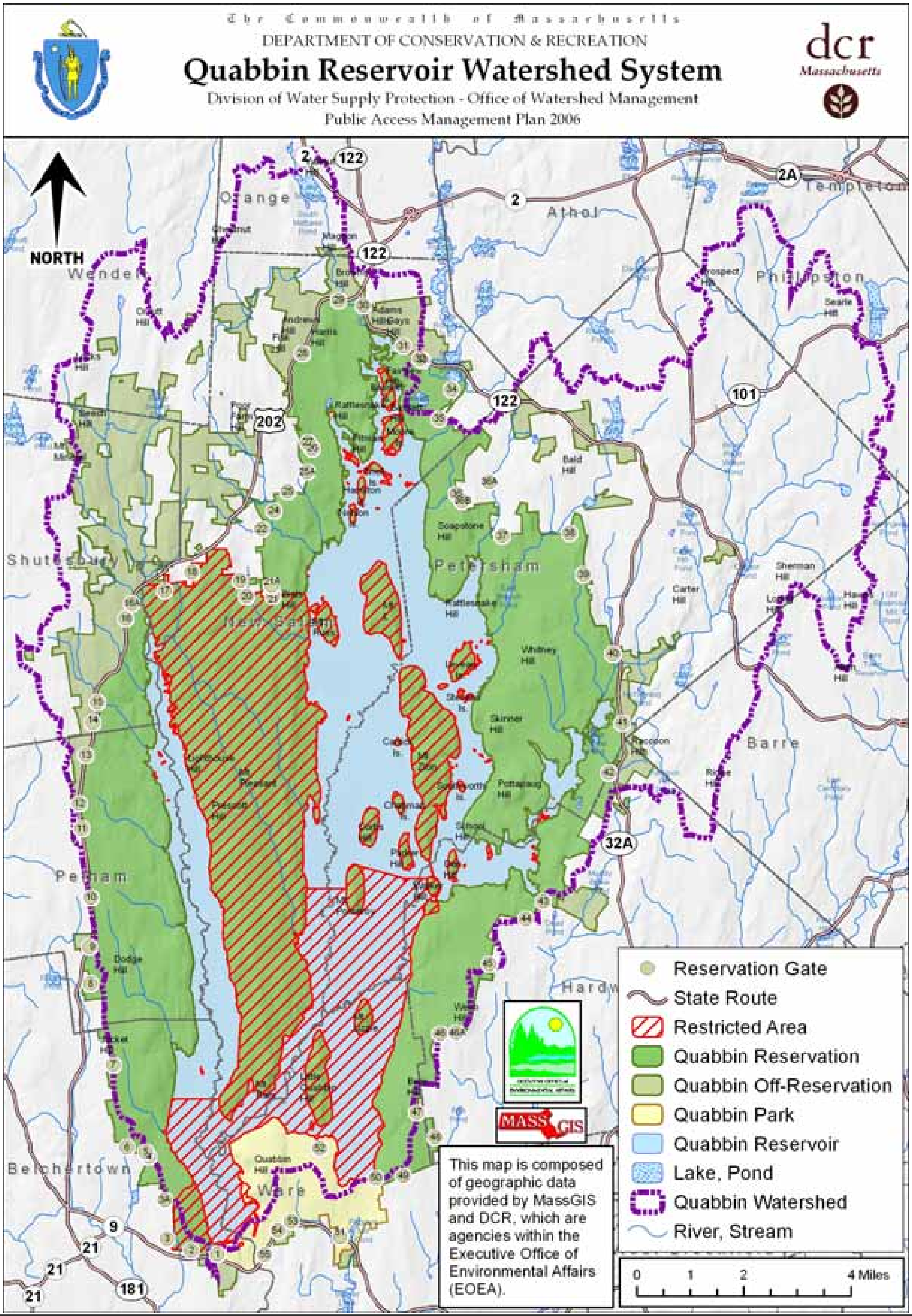


Table 17: Quabbin Reservoir Watershed Public Access Rules Summary

Activity	Quabbin Park	Quabbin Reservation	Off-Reservation	Quabbin Reservoir	Regulating Ponds[a]	Off-Watershed Ponds[b]
VEHICLE ACCESS						
Driving for Sightseeing	□ 1	Ò	Ò	Ò	Ò	Ò
Snowmobiling	Ò	Ò	□ 2	Ò	Ò	Ò
ATV Riding	Ò	Ò	Ò	Ò	Ò	Ò
Bicycling -Designated Roads	□ 3	□ 4	□ 5	Ò	Ò	Ò
Off-road Bicycling	Ò	Ò	Ò	Ò	Ò	Ò
Sledding	□ 6	□	□	Ò	Ò	□
FOOT ACCESS						
Walking/Hiking/Snowshoeing	□ 7	□ 7	□	Ò	Ò	□
Cross-country Skiing	Ò	Ò	□	Ò	Ò	Ò
Hunting/Trapping	Ò 8	Ò 8	□	Ò	Ò	Ò
Ice Fishing/Ice Skating	Ò	Ò	□	Ò	Ò	□ 9
Shore Fishing	Ò 10	□ 11	□ 12	□ 11	□ 11	□ 12
WATER ACCESS						
Boat Fishing	Ò	Ò	□ 13	□ 14	□ 14	□ 13
Canoeing/Kayaking/Boating	Ò	Ò	Ò	Ò	□ 14	□ 15
Wading (fishing, launching)	Ò 16	□ 17	□ 17	Ò 18	□ 18	□ 16
Swimming	Ò	Ò	Ò	Ò	Ò	Ò
OTHER ACCESS						
Group Activities (e.g., weddings)	□ 19	□ 19	□ 19	Ò	Ò	Ò
Geocaching/Questing	□ 20	□ 20	□ 20	Ò	Ò	Ò
Wildlife/Bird Watching	□ 7	□ 7	□ 7	□ 7	□ 7	□ 7
Night Access	Ò 21	□ 22	□ 22	Ò	Ò	□ 21
Organized Sports	Ò 24	Ò 24	Ò 24	Ò	Ò	Ò
Dogs/ Other Animals	Ò	Ò	Ò	Ò	Ò	Ò
Horseback Riding	Ò	Ò	Ò	Ò	Ò	Ò
Collecting/Metal Detecting	Ò	Ò	Ò	Ò	Ò	Ò
Camping	Ò	Ò	Ò	Ò	Ò	Ò
Fishing Derbies	Ò	Ò	Ò	Ò	Ò	Ò
Target Shooting	Ò	Ò	Ò	Ò	Ò	Ò
Advertising	Ò	Ò	Ò	Ò	Ò	Ò
Marking–Trail/Roads (unauthorized)	Ò	Ò	Ò	Ò	Ò	Ò
Alcohol (possession of)	Ò	Ò	Ò	Ò	Ò	Ò
Other	**Please call the Quabbin Visitor Center 413-323-7221 or Watershed Ranger Station 413-323-0192**					

LEGEND: **Prohibited – Ò** **Allowed - general restrictions – □** **Specific Conditions – □ #**

[a] The areas on the reservoir above the horseshoe dams at Gates 31 and 43

[b] South Spectacle, Bassett, and Peppers Mill Ponds

General Restrictions:

General public access within the Quabbin Reservoir Watershed System is restricted to one hour before sunrise and one hour after sunset through gates or designated (posted) areas only. Any activity which injures or defaces the property of the Commonwealth is strictly prohibited. This chart is based on the Watershed Protection Regulations 350 CMR 11.00, copies of which are available at the Quabbin Visitor Center. Littering is strictly prohibited. Carry in/Carry out. Don't feed wildlife.

Specific Restrictions:

[1] The Winsor Dam and Goodnough Dike have restricted vehicle access for security reasons.

[2] Snowmobiling is allowed only on the DCR designated trail located on Off-Reservation land. 304 CMR 12.29 applies.

[3] Bicycling is only allowed on designated roads in Quabbin Park. See DCR Bicycling maps. Helmets and protective gear are required by MA law for children under 16 years of age and recommended for others

[4] Bicycling is allowed only on designated roads through DCR gates 29, 30, 31, 35, 40, 43A & B, and 44. Bicycling is only allowed on designated roads through Gate 8 during fishing season. See DCR Bicycling map for designated roads.

[5] Bicycling is allowed on main forest roads only within Off-Reservation lands with seasonal restrictions (e.g., mud season).

[6] Sledding or any other kind of sliding activity is prohibited on the reservoir, the dams and other structures.

[7] Walking, hiking, or snowshoeing access is allowed within the Quabbin Reservoir Watershed system, except in restricted areas (e.g., Prescott Peninsula, posted Administration Areas, Reservoir islands and along the baffle dams-November 15 – June 15).

[8] Hunting and Trapping are prohibited except by special permit during the Quabbin Controlled Deer Hunt and associated Paraplegic Hunt. Contact the Quabbin Visitor Center for more information.

[9] Ice fishing, ice skating, and carry-in boat access allowed on three Off-watershed ponds: South Spectacle, Bassett and Peppers Mill Ponds only. Please call Watershed Rangers, if accessing, as a courtesy at 413-323-0192.

[10] No fishing in Quabbin Park except catch-and-release fly fishing (allowed all year) below the Winsor Dam in the Swift River, unless posted.

[11] Shore fishing along the Reservoir and along streams is permitted between Gates 8-West Branch Swift River, and 22-44 (except on baffle dams), by foot, during the designated Quabbin Fishing Season only. See the current Quabbin Fishing Guide and Map available at the Quabbin Visitor Center.

[12] Shore fishing within off-reservation lands and along off-watershed ponds is allowed year round according to State Fishing regulations.

[13] Carry-in boat access is allowed on off-watershed ponds. See Night Access Policy, if applicable.

[14] Boat access on designated areas of reservoir or regulating ponds requires valid MA Fishing License and size/motor restrictions. Wearing boots is mandatory if wading while launching or removing boats at designated areas from the Reservoir. Fishing access using canoes, kayaks, or jon boats is allowed only through Gate 31 above regulating dam and through Gate 43 on Pottapaug Pond with restrictions. Contact the Quabbin Visitor Center at 413-323-7221 for more information regarding current Fishing Guide.

[15] Allowed subject to MA Boating regulations. Please call Watershed Rangers, if accessing, as a courtesy at 413-323-0192

[16] Wading is allowed Off-watershed below the Winsor Dam Power Station on the Swift River

[17] Wading with boots is allowed between Gate 8-West Branch Swift River, and Gate 22-44, except in restricted areas, and in Off-Reservation tributaries.

[18] Wading is prohibited except while launching or removing boats while wearing boots, at designated boat launch areas.

[19] Allowed without a permit for groups of less than 25 individuals and/or less than 10 cars and/or 10 motorcycles. Permit required for group of 25 through 100 individuals and/or 10-40 cars/motorcycles or 1 bus. Permit and Ranger required for larger groups or other combinations.

[20] Special permit from Visitor Center required for any cache placement.

[21] Night access within Quabbin Park is prohibited with two exceptions. It is allowed without a permit on Swift River below Y pool, if access is from Route 9, and on Peppers Mill Pond.

[22] Night access within Quabbin Reservation is allowed by permit for pedestrians only through Gates 16, 31, 35, 41, and 43 only during the designated Quabbin Fishing season. Night access directly from 122 is allowed without a permit on South Spectacle Pond (off-watershed). Night access is allowed on Off-Reservation lands with special permit. Contact Quabbin Visitor Center for permit information.

[23] South Spectacle, Bassett, and Peppers Mill Ponds.

[24] Prohibited except with written permission from the Commissioner.

2.4.2 *Current Forest Conditions*

2.4.2.1 Quabbin Forest Types and Acreages

In 1998, Quabbin forestry and natural resources staff, in conjunction with photo interpretation/GIS staff at the University of Massachusetts, began work to complete current forest typing of the DCR/DWSP properties surrounding Quabbin Reservoir, based on digital, aerial orthophotography that was flown in 1993. The forestry staff identified forest types based on a combination of 1 meter and 0.5 meter resolution digital orthophoto quadrangle sheets and field checking as needed, and drew these on mylar overlays. These mylars were registered to the statewide GIS and scanned to produce digital shape files for use in a wide variety of GIS applications. Where changes had occurred since the date of the photography (e.g., red pine plantations converted to mixed native composition), these changes were included in the typing, so that this datalayer can be considered current as of 1998-1999. **Table 18** describes the current composition of the Quabbin forest based on this typing project.

Table 18: Quabbin Forest Types and Acreages

Category	Overstory type	Code	Description	Total Acres	Percent of Total
Softwoods	White pine (WP)	1	Eastern white pine is pure or predominant. Generally moist sandy loam soils.	6,518	11%
Softwoods	White pine / Hemlock (WK)	2	Eastern white pine and eastern hemlock and a large assortment of hardwoods. Pine usually dominates.	2,586	4%
Mixed	White pine / Hardwood (WH)	3	Eastern white pine, northern red oak, and other hardwoods predominate with red maple as the chief associate. Tends to develop into WK.	7,901	14%
Mixed	White pine / Oak (WO)	4	Eastern white pine and northern red oak or black oaks predominate. Type has some chestnut oak but usually black, red, or scarlet oaks plus assorted other hardwoods.	3,770	6%
Softwoods	White pine / pitch pine	5	Past history of fire on dry, sandy soils has established a pitch pine component in this otherwise predominantly white pine type.	9	<1%
Softwoods	Hemlock (HK)	6	Eastern hemlock is pure or predominant over many other associates.	1,654	3%
Mixed	Hemlock / hardwood (HH)	7	Hemlock and yellow birch dominate, with sugar maple, beech, and red oak as associates. Moist sites.	2,922	5%
Softwoods	Norway spruce (NS)	8	Planted Norway spruce	?	<1%
Softwoods	Red / white spruce (RS)	9	Plantations of red and/or white spruce with associated minor component of yellow birch, sugar and/or red maple, and beech	79	<1%

Category	Overstory type	Code	Description	Total Acres	Percent of Total
Softwoods	Larch (tamarack) (TK)	10	Planted larch is pure or predominant. Moist sites.	5	<1%
Softwoods	Red pine (RP)	11	Although able to reproduce naturally, most of this type was planted, sometimes in alternating rows with white pine.	1,550	3%
Hardwoods	Northern red oak (RO)	12	Northern red oak is predominant with other oaks as chief associates.	6,907	12%
Hardwoods	Oak / hardwood (OH)	13	Oaks and hickories dominate stands containing red, white, black, and scarlet oak and other associated hardwoods. Sites are usually moderately well-drained, with average soil depths. Usually not ridgetops.	8,673	15%
Hardwoods	Oak, mixed: dry site (OM)	14	Black and white oaks predominate, although red oak is present, along with red maple and birches. These are frequently poor sites with thin, excessively drained soils, found toward the tops of ridges.	7,005	12%
Wetlands	Wooded wet – deciduous	15	Forested wetlands dominated by red maple with a large number of other associated species.	732	1%
Hardwoods	Black birch/red maple/cherry	16	Black birch and red maple predominate. Generally a pioneer, early-successional type.	1,617	3%
Other types	Poplar / grey birch	17	Also a pioneer type, with paper birch, pin cherry, and red maple as common associates.	225	<1%
Other types	Abandoned orchard	18	Planted fruit trees which persist despite competition, or have been retained by management.	8	<1%
Other types	Grasses / herb cover	19	Land which is maintained in grasses or herbaceous cover but not associated with administrative areas.	311	1%
Other types	Upland brush	20	Recently abandoned fields in a wide mix of tree, shrub, and herbaceous cover.	111	<1%
Wetlands	Marsh	21	Soil is saturated and often covered with six inches to as much as three feet of standing water during the growing season. Wetland and aquatic vegetation may include sedges, cattails, pickerelweed, water lilies, or duckweed.	257	<1%
Hardwoods	Northern hardwoods	22	Moist, rich sites dominated by white ash, sugar maple, yellow birch.	1,973	3%

Category	Overstory type	Code	Description	Total Acres	Percent of Total
Wetlands	Shrub swamp	23	Soil saturated during growing season. Common woody species include alder, buttonbush, dogwood, willow. Tussock sedges also common.	459	1%
Wetlands	Bog	24	Typically acid, peaty, saturated soil with characteristic mat of sphagnum. Black spruce, tamarack, red maple may be present. Also heath shrubs, cranberries, pitcher plants, sedges.	75	<1%
Wetlands	Wooded wet – coniferous	25	Wetlands with a coniferous overstory.	188	<1%
Wetlands	Wooded wet – mixed	26	Wetlands with a mixed conifer/deciduous overstory.	418	1%
Wetlands	Beaver meadow	27	Conditions may resemble other type classes, but originated by beaver.	883	2%
Administrative	Power line	28	Power line on poles or buried telephone or pipe lines.	289	<1%
Administrative	Administration areas	29	Structures, parking areas, fishing areas, others.	154	<1%
Administrative	Lawns, ornamental plantings	30	Areas around administrative buildings, within Quabbin Park, on and adjacent to dams and dikes that are dominated by mowed grass and ornamental plantings.	88	<1%
Administrative	Gravel pit	34	Areas from which gravel is currently or has been historically extracted and are not currently forested.	17	<1%
Hardwoods	Red maple	35	Red maple dominates; hardwood associates include oaks and birches.	1,028	2%
Softwoods total				12,401	21%
Hardwoods total				27,203	47%
Mixed woods total				14,593	25%
Wetland types total				3,012	5%
Other types				655	1%
Administrative total				548	1%
Grand Total				**58,412**	**100%**

For the 54,197 acres typed as non-wet forest land, 23% is dominated by softwoods, 50% is dominated by hardwoods, and 27% is mixed hardwoods and softwoods. Wetlands total 3,012 acres, of which 1,268 are wooded.

2.4.2.2 Exceptional Forests

Both Fred Hunt, who supervised forestry in the early 1960s at Quabbin, and Bruce Spencer, Chief Quabbin Forester from 1965 to 2006, identified areas within the forest that included exceptional individual trees or stands of trees. Hunt referred to a series of exceptional trees he located and mapped as his "museum pieces"; Spencer took the time before his retirement to map areas of exceptional trees or stands that he had found and followed during his 40 years in these woods. All DWSP foresters have at one time or another discovered stands or trees or other landscape features that for one reason or another greatly surpass the average. There is shared concern that these areas might go unacknowledged if they are not documented and could be inadvertently altered or lost. DWSP has begun an effort to document these areas and to maintain both spatial and database records of their location and significance, and then to prescribe individualized management approaches in order to conserve this resource.

2.4.2.3 Results from Quabbin Continuous Forest Inventory

2.4.2.3.1 Brief History of Continuous Forest Inventory (CFI)

Early in his tenure as Forest and Park Supervisor for DWSP properties in the early 1960s, Fred Hunt recognized the potential value of installing a Continuous Forest Inventory system at Quabbin, based on the USDA Forest Service design. The intent was to gather periodically updated information on the current condition of the forest, sufficient to guide the improvement of both water and forest values on the watershed. The objectives included an assessment of the current vegetative cover against an ideal composition and structure, and the calculation of sustainable periodic yields that might be attained in the process of managing toward that ideal. This system of plots has been remeasured at least every ten years since 1960, producing a valuable, probably unique, record of the growth and change in a large, contiguous, managed forest in central New England. In looking through the sample results shown below, readers should bear in mind that these figures are from a forest that has been under active management since the 1960s, in contrast to much of the forest in Massachusetts. They are also a tribute to the silvicultural care provided by Bruce Spencer, the Chief Forester at Quabbin from 1965 to 2006.

Hunt installed 347 CFI plots at Quabbin beginning in April 1960. Plots were established at the intersections of a ½ mile x ½ mile grid that was laid out over topographic maps covering all of the land under state care and control at Quabbin, including islands. All CFI plots are 1/5 acre in size (52.66 feet in radius) and because they are on a ½ mile grid, each represents 160 acres of the watershed forest, so the initial CFI represented 55,520 acres, the approximate holding at the time. Plot center was identified with a hardwood stake and witness trees. In this first measurement, all softwoods with a diameter at breast height (DBH) of 9.0”and above and all hardwoods 11.0” DBH and above were measured. On a random sample of all plots, all trees greater than 5.0” DBH were measured, in order to sample younger growing stock. Each tree was numbered and that number and the permanent point for measuring DBH were painted on the tree. Data recorded for each tree measured in 1960 included plot and tree number, species, DBH to the nearest $1/10^{th}$ inch, merchantable height, and various determinations of soundness and product value of the tree. Plot information included forest type, stocking and size class, land use, disturbance, accessibility, and recommended future silviculture.

Full details of the 1960 CFI measurement are included in Hunt’s Masters thesis at the University of Massachusetts. Below are a few highlights from that report:

1. Stands younger than 20 years old occupied less than 8% of the forest; stands older than 60 years old were estimated to occupy even less.
2. Sawtimber on the 55,520 acre forest totaled an estimated 124,455,000 board feet, of which 45% was white pine and 32% was oak. Current value of all sawtimber was estimated at $1,760,580 based on an average stumpage value of $10.60 per thousand board feet. Poletimber was estimated to total about 260,000 cords.
3. The Chestnut blight and the hurricane of 1938 resulted in two-storied stands of sawlog residuals above smaller trees, on a total of about 17,000 acres.
4. 65% of the sawtimber trees, by volume, were rated as good to excellent in vigor. Just 2% of the sawtimber trees were rated as “dying”.
5. Metal was found in about 1% of the total sawtimber by volume, ranging from old fence wire to railroad spikes and horseshoes.
6. The white pine weevil was rated as the most damaging of the biological agents affecting the

forest, while white pine blister rust and gypsy moth were determined to be well under control. Dutch elm disease was finishing off most of the remaining elm trees.

7. Regeneration (trees 3 feet tall to 4.9" dbh) averaged 254 stems per acre, but some areas, and Prescott Peninsula in particular, showed no regeneration of valuable species during the previous fifteen years, because of deer browsing.
8. Annual growth of sawtimber was estimated to be about 4.7 million board feet at that time.

Note that these plots are not removed from management; they are treated according to the prescription for the surrounding stand. The Quabbin CFI plots were remeasured in 1965, 1970, 1980, 1990, and 2000, and partially remeasured in 1995. The variables measured from year to year have changed somewhat, but all trees greater than 5.5" dbh on all plots have been measured since 1965. DBH and some measurement of height and vigor have been recorded consistently, and subplots to measure seedlings and saplings have been added in recent years. As a water supply management agency, DWSP's priority for information from CFI has focused on changes in species composition and size or age class distribution, but the data also allow calculations of growth in volume and value.

2.4.2.3.2 2000 remeasurement

The 2000 CFI remeasurement began at the end of the 2000 growing season and was completed by mid May of 2001. Sonar measuring devices enabled a distance and bearing measurement from plot center for each tree on the plot, making it possible to map and model the spatial components of stand development. A total of 326 plots were measured, 304 of which were also measured in 1990. In addition to tree measurements, plot measurements have been recorded every decade, and the 2000 plot measurements added greater detail on types of disturbances and interference from invasive plants, both native and non-native. Tree data in 2000 included species, DBH, crown class, product lengths and potential, and wildlife value, among others.

There are endless questions that can be addressed by the information in the CFI plots, but only a few of these are summarized in this plan. DWSP first looks at changes in species composition in the most recent decade, by charting the basal area stocking of each species at the beginning and end of the period, and accounting for changes as growth, mortality, or harvesting. **Table 19** shows the results for the most recent decade. These figures show the basal area (square feet at 4.5 feet above the ground) changes on the 304 plots (representing 48,640 managed acres) that were measured in both 1990 and 2000 (there are minor changes in plots measured, for instance due to losses from beaver flooding of plots, or new plots added on land recently acquired).

296 of the 326 plots measured in 2000-2001 were designated as "regular management" plots, 14 plots were located on islands, 6 within designated "natural areas", 9 in areas designated as wetlands, and 1 in an area designated as too steep to manage. Some of these plots had been previously measured in 1980, but not in 1990. As each plot represents 160 acres, the 296 "regular management" plots represent 47,360 acres, which was approximately the acreage in 2000 of actively managed Division-controlled forest surrounding Quabbin Reservoir (>10,000 acres were reserved from active management).

Table 19: Total CFI Basal Area (sq ft) by Species and Changes from 1990 to 2000

Species	1990 BA	% of 1990 BA	BA Died	%	BA Cut	%	Growth	%	New	2000 BA	% of 2000 BA	BA Change	% Change
White pine	1726	26.9%	47	2.7%	254	14.7%	364	21.1%	43	1832	28.2%	106	6%
Red pine	467	7.3%	10	2.1%	303	64.9%	28	6.0%	0	182	2.8%	-285	-61%
Hemlock	529	8.3%	18	3.4%	58	11.0%	97	18.3%	29	579	8.9%	50	9%
Spruces	36	0.6%	3	8.3%	10	27.8%	4	11.1%	0	27	0.4%	-9	-25%
Pitch pine	8	0.1%	3	37.5%	1	12.5%	1	12.5%	0	5	0.1%	-3	-38%
Larch	10	0.2%	0	0.0%	0	0.0%	4	40.0%	0	14	0.2%	4	40%
Red oak	1069	16.7%	6	0.6%	57	5.3%	259	24.2%	10	1275	19.6%	206	19%
Black oak	435	6.8%	11	2.5%	71	16.3%	81	18.6%	7	441	6.8%	6	1%
Scarlet oak	5	0.1%	0	0.0%	1	20.0%	2	40.0%	0	6	0.1%	1	20%
White oak	246	3.8%	9	3.7%	29	11.8%	32	13.0%	6	246	3.8%	0	0%
Chestnut oak	38	0.6%	4	10.5%	2	5.3%	6	15.8%	2	40	0.6%	2	5%
Sugar maple	104	1.6%	2	1.9%	2	1.9%	17	16.3%	3	120	1.8%	16	15%
Red maple	878	13.7%	79	9.0%	100	11.4%	117	13.3%	45	861	13.3%	-17	-2%
Yellow birch	92	1.4%	6	6.5%	5	5.4%	12	13.0%	4	97	1.5%	5	5%
Black birch	296	4.6%	10	3.4%	43	14.5%	56	18.9%	21	320	4.9%	24	8%
White birch	111	1.7%	20	18.0%	18	16.2%	10	9.0%	3	86	1.3%	-25	-23%
Beech	9	0.1%	2	22.2%	1	11.1%	3	33.3%	0	9	0.1%	0	0%
White ash	218	3.4%	20	9.2%	11	5.0%	37	17.0%	3	227	3.5%	9	4%
Hickory	85	1.3%	3	3.5%	3	3.5%	11	12.9%	2	92	1.4%	7	8%
Elm	3	0.0%	2	66.7%	0	0.0%	0	0.0%	0	1	0.0%	-2	-67%
Poplar	12	0.2%	2	16.7%	0	0.0%	2	16.7%	0	12	0.2%	0	0%
Tupelo	3	0.0%	0	0.0%	0	0.0%	0	0.0%	0	3	0.0%	0	0%
Butternut	1	0.0%	1	100.0%	0	0.0%	0	0.0%	0	0	0.0%	-1	-100%
Black cherry	28	0.4%	3	10.7%	7	25.0%	2	7.1%	1	21	0.3%	-7	-25%
Ironwood	1	0.0%	0	0.0%	0	0.0%	0	0.0%	0	1	0.0%	0	0%
Grey birch	2	0.0%	1	50.0%	0	0.0%	0	0.0%	0	1	0.0%	-1	-50%
Totals	**6412**	**100%**	**262**	**4.1%**	**976**	**15.2%**	**1145**	**17.9%**	**179**	**6498**	**100%**	**86**	**1.3%**

In 1998-1999, DWSP staff completed a project to update forest typing (see Section 1.10.2.3), using the most recent digital orthophotography and field surveys and digitizing the results to the DCR GIS. A comparison between the mapped acreage of forest types and the acres of each type represented by the current CFI was completed to verify representation. Results of this comparison are shown in **Table 20**. Some of the smaller forest types, such as coniferous wooded wetlands and pure red maple types are under-represented, while the largest over-representations are with the white pine/oak and the dry site oak types. The explanation may be the overlap between these types and others, such as white pine/hardwood or oak/hardwood, which are underrepresented by the current CFI. Note also that the typing of CFI plots is somewhat more localized than landscape level forest typing.

Table 20: CFI Plot Distribution Compared to Acreages by Forest Type

All plots, including islands, wetlands, etc (each 1/5 acre plot represents 160 acres of the forest)						
Overstory code	**Overstory name**	**# of CFI plots**	**Acres represented**	**Acres in GIS**	**Difference**	**CFI plots needed**
1	White pine	39	6,240	6,518	278	2
2	White pine / hemlock	6	960	2,586	1,626	10
3	White pine / hardwood	41	6,560	7,901	1,341	8
4	White pine / oak	41	6,560	3,770	(2,790)	(17)
5	White pine / pitch pine	0	-	9	9	0
6	Hemlock	3	480	1,654	1,174	7
7	Hemlock / hardwood	24	3,840	2,922	(918)	(6)
8	Norway spruce	0	0	- ? -	-	-
9	Red / white spruce	1	160	79	(81)	(1)
10	Larch	1	160	5	(155)	(1)
11	Red pine	12	1,920	1,550	(370)	(2)
12	Red oak	42	6,720	6,907	187	1
13	Oak / hardwood	45	7,200	8,673	1,473	9
14	Oak, mixed: dry site	57	9,120	7,005	(2,115)	(13)
15	Wooded wet - deciduous	5	800	732	(68)	(0)
16	Black birch/red maple/cherry	8	1,280	1,617	337	2
17	Poplar / grey birch	0	-	225	225	1
18	Abandoned orchard	0	-	8	8	0
19	Grasses / herb cover	1	160	311	151	1
20	Upland brush	1	160	111	(49)	(0)
21	Marsh	1	160	257	97	1
22	Northern hardwoods	20	3,200	1,973	(1,227)	(8)
23	Shrub swamp	1	160	459	299	2
24	Bog	1	160	75	(85)	(1)
25	Wooded wet - coniferous	0	-	188	188	1
26	Wooded wet - mixed	2	320	418	98	1
27	Beaver meadow	4	640	883	243	2
28	Powerline	0	-	289	289	2
29	Administration areas	1	160	154	(6)	(0)
30	Lawns, ornamental plantings	0	-	88	88	1
34	Gravel pit	0	-	17	17	0
35	Red maple	2	320	1,028	708	4
Total		**359**	**57,440**	**58,412**	**972**	**6**

2.4.2.3.3 Species Distribution

Based on the basal area totals from the 11,000+ trees in the 2000 CFI remeasurement, the current distribution of individual tree species across the Quabbin DWSP properties is shown in **Table 21**. On this basis, white pine still dominated the stocking, followed by red oak and red maple. Hemlock still represented 8.9% of the stocking total in 2000, a figure which is likely to decline in the next decade. Early successional or pioneer species such as white birch, poplar, and grey birch occupy minor components of the forest. Butternut, an endangered species due to disease, has all but disappeared from the watershed.

Table 21: Tree Species Distribution in 2000 CFI

Species	2000 BA	% Total
White pine	1832	28.2%
Red oak	1275	19.6%
Red maple	861	13.3%
Hemlock	579	8.9%
Black oak	441	6.8%
Black birch	320	4.9%
White oak	246	3.8%
White ash	227	3.5%
Red pine	182	2.8%
Sugar maple	120	1.8%
Yellow birch	97	1.5%
Hickory	92	1.4%
White birch	86	1.3%
Chestnut oak	40	0.6%
Spruces	27	0.4%
Black cherry	21	0.3%
Larch	14	0.2%
Poplar	12	0.2%
Pitch pine	5	0.1%
Scarlet oak	6	0.1%
Beech	9	0.1%
Elm	1	0.0%
Tupelo	3	0.0%
Butternut	0	0.0%
Ironwood	1	0.0%
Grey birch	1	0.0%

2.4.2.3.4 Size Distribution

In the year 2000 Continuous Forest Inventory, measurements were taken on 10,342 live trees that were greater than 5.6 inches in diameter at breast height (4.5 feet). These trees are placed in diameter classes for convenience, which accumulate all the trees that are between 0.6 inches less and 0.5 inches more than the diameter (e.g., a tree that is 5.6" to 6.5" DBH would be classified as a 6 inch diameter tree). The distribution of size classes is shown in **Table 22**.

Table 22: Diameter Distribution on CFI in 2000

DBH	# of Trees	% of Total
6	1,548	14.97%
7	1,384	13.38%
8	1,182	11.43%
9	1,076	10.40%
10	954	9.22%
11	813	7.86%
12	677	6.55%
13	615	5.95%
14	435	4.21%
15	333	3.22%
16	290	2.80%
17	231	2.23%
18	200	1.93%
19	165	1.60%
20	118	1.14%
21	77	0.74%
22	65	0.63%
23	45	0.44%
24	27	0.26%
25	28	0.27%
26	24	0.23%
27	15	0.15%
28	9	0.09%
29	13	0.13%
30	5	0.05%
31	6	0.06%
32	-	0.00%
33	3	0.03%
34	1	0.01%
35	1	0.01%
36	-	0.00%
37	1	0.01%
45	1	0.01%
Total	**10,342**	**100.00%**

2.4.2.3.5 Volumes and Growth

Total standing volume in board feet, by species, was calculated using the Form 78 International ¼” Rule for sawlog volumes, a standard measure used frequently in Massachusetts (**Table 23)**. On this basis, White Pine continues to dominate the forest, representing twice as much volume as Red Oak, the second most abundant species by sawlog volume. Hemlock in 2000 carried the third greatest volume of all species, a further testament to the importance of this species that unfortunately is being gradually diminished by an exotic insect pest, the Hemlock Woolly Adelgid (see section 5.2.3).

The total standing volume estimated in 2000 was 527,300,000 board feet. The standing volume in 1960, when Fred Hunt first measured the CFI plots, was estimated at 124,455,000 board feet. Between these two years, the Division has completed approximately 1,000 timber sales, which removed approximately 130 million board feet in improvement thinnings and regeneration harvests, yet forest sawlog volumes grew by 424%, or 10.6% annually *above and beyond* the harvesting that took place in this period. **Table 24** utilizes the volume estimates from the 1990 CFI remeasurement to compare to the volume estimates from the 2000 CFI remeasurement, in order to generate a current growth rate by species. Based on this calculation, the average annual growth was 282 board feet per acre across the Division forest at Quabbin. The total annual growth for the forest was estimated at more than 15 million board feet, so that the estimated annual harvest of 7.5 million board feet was just under 50% of the annual growth (actual annual harvest rates average approximately 5 million board feet, or 33% of the estimated annual growth).

Table 23: Sawlog Volumes by Species Based on 2000 CFI

Species	Standing Board Foot Volume in 2000	Board Foot Volume as Percent of Total
White Pine	230,058,000	43.6%
Red Oak	115,407,000	21.9%
Hemlock	39,265,000	7.4%
Black Oak	28,810,000	5.5%
Red Maple	27,799,000	5.3%
Red Pine	23,806,000	4.5%
White Oak	14,151,000	2.7%
White Ash	13,459,000	2.6%
Black Birch	12,402,000	2.4%
Sugar Maple	5,783,000	1.1%
Other Softwoods	5,316,000	1.0%
Yellow Birch	4,107,000	0.8%
Paper Birch	3,576,000	0.7%
Other Hardwood	2,864,000	0.5%
Scarlet Oak	497,000	0.1%
TOTAL	**527,300,000**	**100.0%**

Table 24: Annual Board Foot Volume Growth Estimated from 1990 and 2000 CFI Measurements

		GROWTH		HARVEST	
Overstory Type	**Acres (GIS)**	**Av Annual BF/acre**	**Total annual BF growth**	**Av Annual BF/ac cut**	**Total annual BF cut**
White pine	6,518	506	3,297,109	376	2,451,944
White pine/hemlock	2,586	389	1,005,716	102	264,834
White pine/hardwood	7,901	345	2,721,975	141	1,116,837
White pine/oak	3,770	359	1,354,902	104	390,903
Hemlock	1,654	276	457,193	281	465,100
Hemlock/hardwood	2,922	253	738,096	48	139,875
Spruce	79	431	34,029	44	3,454
Larch	5	636	3,180	0	0
Red pine	1,550	359	556,485	683	1,058,205
Red oak	6,907	237	1,638,468	11	74,235
Oak/hardwood	8,673	203	1,757,011	35	307,494
Oak mixed, dry site	7,005	167	1,167,911	46	323,409
Wooded wet - deciduous	732	199	145,879	0	0
Birch/maple/cherry	1,617	199	321,304	0	0
Northern hardwoods	1,973	185	365,440	301	593,297
Wooded wet - conifers	188	16	3,016	0	0
Red maple	1,028	50	51,121	0	0
Total	**55,108**	**282**	**15,524,694**	**136**	**7,502,702**

2.4.2.4 Regeneration Conditions

The Division has been monitoring the conditions of tree regeneration in the forest understory at Quabbin intensively since 1989, primarily to provide guidance for efforts to control the impacts of white-tailed deer. The regeneration monitoring program and current status is detailed in Appendix IV at the back of this plan. By way of summary of current conditions, the deer impact control program has been very successful. In the 15 years between the pre-control sampling in 1989 and the most recent watershed-wide sampling, regeneration has recovered dramatically (**Table 25**), with regeneration that is above 4.5 feet (the upper height of deer browsing) increasing ten-fold on areas within Quabbin Reservation, where hunting had been prohibited until 1991. (NOTE: also see **Appendix IV**). There remain shortfalls in some of the species that are most highly preferred by deer, and black birch and white pine continue to be the strongest component of the on-Reservation regeneration response, but overall, deer control has been very effective in recovering the regenerative ability of the forest. So long as deer populations are maintained at close to current levels, the greatest threat to regeneration in the coming decade may be from an expansion of the moose populations. A moose weighs approximately ten times the weight of a deer. An individual moose consumes approximately 50 pounds of green biomass per day to maintain its mass.

Table 25: Tree Regeneration 1989 vs. 2004

Area	Year	Regeneration 1 ft tall to 4.5 feet	Regeneration > 4.5	Total regeneration
Off Reservation	1989	1,960 stems per acre	1,140 stems per acre	3,100 stems per acre
	2004	2,071	1,404	3,475
On Reservation	1989	770	130	910
	2004	3,187	1,344	4,531

(Note: see Appendix IV for regeneration species composition and other details)

2.5 Quabbin Wildlife

2.5.1 Current Conditions

All species of wildlife depend on the existence and quality of various habitat types. Some species require a very specific habitat to survive (e.g., wood frogs and vernal pools), while other species can exist in a variety of habitats (e.g., coyote). The Quabbin watershed is comprised of a mosaic of habitats. DCR owned land within the watershed is largely forested, while privately owned lands are comprised of small farms, fields, woodlots, and residential areas. Although as a whole the landscape is fragmented, DCR owned land within the watershed is large and relatively contiguous. The undeveloped and relatively unbroken nature of these lands is a tremendous benefit to all wildlife species.

Quabbin supports an impressive variety and abundance of wildlife. Forests provide habitat for a diversity of birds and mammals, including moose, white-tailed deer, turkey, grouse, fisher, and bears. In addition, Neotropical migrant birds, including black and white warblers, rose-breasted grosbeaks, and scarlet tanagers utilize DCR forests for breeding and migratory rest stops. The Quabbin is dotted with wetlands, streams, and beaver ponds which support a variety of reptiles, amphibians, and birds. There are several large tracts of early successional non-forested habitat within the Quabbin watershed. These large open, grassy areas provide habitat for a variety of species dependent on open lands including eastern meadowlarks, bobolinks, and a variety of invertebrates.

One of the most important aspects of DCR land in the Quabbin watershed for wildlife is its protection from development. Towns across Massachusetts continue to experience growth, often resulting in the loss of open space. The protection DCR lands provide to wildlife species is critical to their long-term survival.

A variety of wildlife species are monitored by Division personnel or other agencies. Breeding bird surveys are conducted yearly along roadsides at two locations. In addition, selected vernal pools are visited, common loons are closely monitored, and the wintering bald eagle population is surveyed each year.

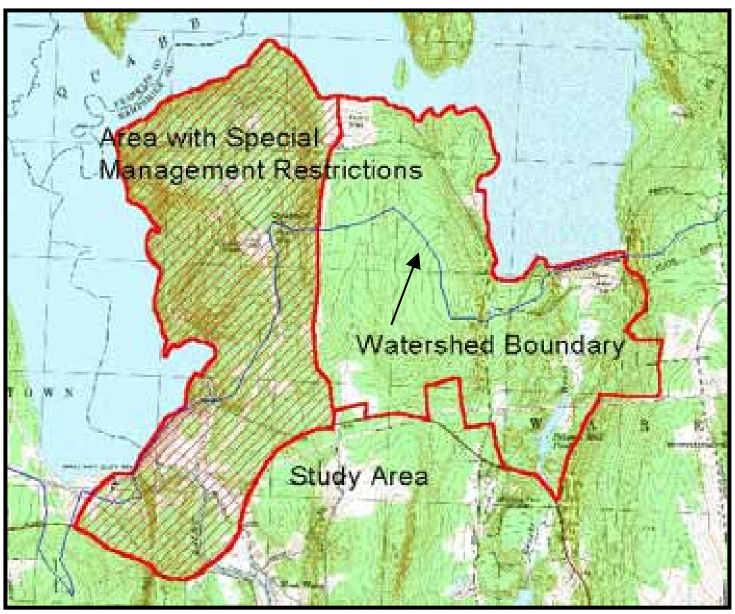
While a great deal of information exists about certain wildlife taxa (e.g., birds and mammals) through information collected from surveys and observations, very little is known about other Quabbin wildlife. A complete species list does not exist, and there is a paucity of information about reptiles, amphibians, insects, butterflies, dragonflies, and other less visible species. It is quite possible that DCR lands within the Quabbin harbor state listed species that have yet to be documented.

2.5.2 Results from Periodic Wildlife Surveys

2.5.2.1 Quabbin Park Deer Population Survey

Quabbin Park, located at the southern end of the Quabbin Reservation, is approximately 3,400 acres in size (**Figure 9**). The Park is the most visited destination of the Reservation, with over 500,000 people visiting the area annually. An extensive network of trails criss-cross the park and provide passive recreation for both occasional visitors and daily walkers. In addition, the Visitor Center, a lookout tower, and several scenic vistas attract educational and recreational groups.

Figure 9: Map of Quabbin Park



Quabbin Park has not been included in the Division's annual managed deer hunt. White-tailed deer management within the Park has consisted only of experiments with electrified deer fencing. Because deer control using electric fences proved unsuccessful within the Park, the Division decided to re-evaluate conditions within the Park and began to examine deer herd densities. A pilot study was initiated in the fall of 2000 to try to assess the feasibility of using distance sampling to study deer densities in the Park. Results from the 2000-2001 pilot study indicated that deer densities were high enough within the Park to initiate a distance sampling study. The objectives of this study were to:

1. Establish a set of random transects within Quabbin Park and develop a protocol for monitoring deer densities from year to year.
2. Estimate deer densities within Quabbin Park during winters 2001-2002 and 2002-2003.

Forty and thirty-eight transects were conducted during 2001-2002 and 2002-2003, respectively (**Table 26**). Surveys started in early to mid November, and the last surveys took place during March of the following year. The average time it took for a single observer to complete a survey was 62.9 and 72 minutes during 2001-2002 and 2002-2003, respectively.

Table 26: Details of Quabbin Park Line-transect Surveys, 2001-2003

	2001-2002	2002-2003
Number of surveys	40	38
Number of km walked	77.05	75.43
Number of observations	75	68
Number of deer seen	248	264
Dates of survey	9 Nov. 2001-7 March 2002	21 Nov. 2002-28 March 2003

Six transects were utilized during the 2001-2002 season. Two new transects were added prior to the 2002-2003 season (**Table 27**). Transects were walked at various times throughout the morning and into early afternoon. Although surveys took place at various times, effort was made to conduct most surveys during early morning and mid-day periods of deer activity in order to optimize effort. On particularly cold or windy days, surveys were conducted at various times throughout the day, because deer were much more likely to be active on these days.

Table 27: Details of Survey Effort for Line-transect Survey in Quabbin Park, 2001-2003

		# Times Surveyed		# Deer Seen	
Transect #	**Length (m)**	**2001-2002**	**2002-2003**	**2001-2002**	**2002-2003**
1	1,978	6	3	11	7
2	1,998	6	6	76	67
3	2,523	1	3	0	19
5	1,790	10	6	102	30
6	1,657	7	5	29	68
7	2,117	10	4	30	10
8	1,849	N/A[1]	4	N/A	39
9	2,406	N/A	7	N/A	34
Total		**40**	**38**	**248**	**264**

[1] Transects 8 and 9 were created prior to the 2002-2003 field season.

Density was estimated using the half-normal + Hermite model of the detection function for both years (Buckland, et al., 1993). The estimated number of deer within Quabbin Park was 233 during the 2001-

2002 study and 247 during the 2002-2003 study (approximately 94 deer per square mile). The estimated effective strip width (ESW) was 44.3 meters and 45.5 meters for 2001-2002 and 2002-2003, respectively. The coefficient of variation for 2001-2002 was approximately 20%. The encounter rate accounted for 61% of the variance in the density estimate. Detection probability accounted for 21.5%, and cluster size variation accounted for the remaining 17.6%. The coefficient of variation for the 2002-2003 season was approximately 19%. Again, the encounter rate accounted for most (56.8%) of the variance in the density estimate. Detection probability and cluster size accounted for 26.6% and 16.6%, respectively.

2.5.2.2 Annual Prescott Beaver Survey Results

Beaver populations in Massachusetts have undergone dramatic changes. By the mid-1700s beaver were extirpated from the state. They were absent from the landscape for close to 200 years until their gradual return in the early 1920s. Beaver were first observed on the Prescott Peninsula in 1952. In 1952, 1960, 1966, and 1968 the number of beaver colonies on the Peninsula was noted through anecdotal records and aerial photographs. From 1969 until the present, annual autumn food cache surveys have been conducted.

Annual surveys of the Peninsula are typically conducted during November each year. A complete shoreline survey is conducted by boat. In addition, all streams, ponds, and other potential habitats on the interior are walked. Active sites are determined by the presence of a food cache and other activity. Active sites are noted, and Universal Transverse Mercator coordinates are recorded.

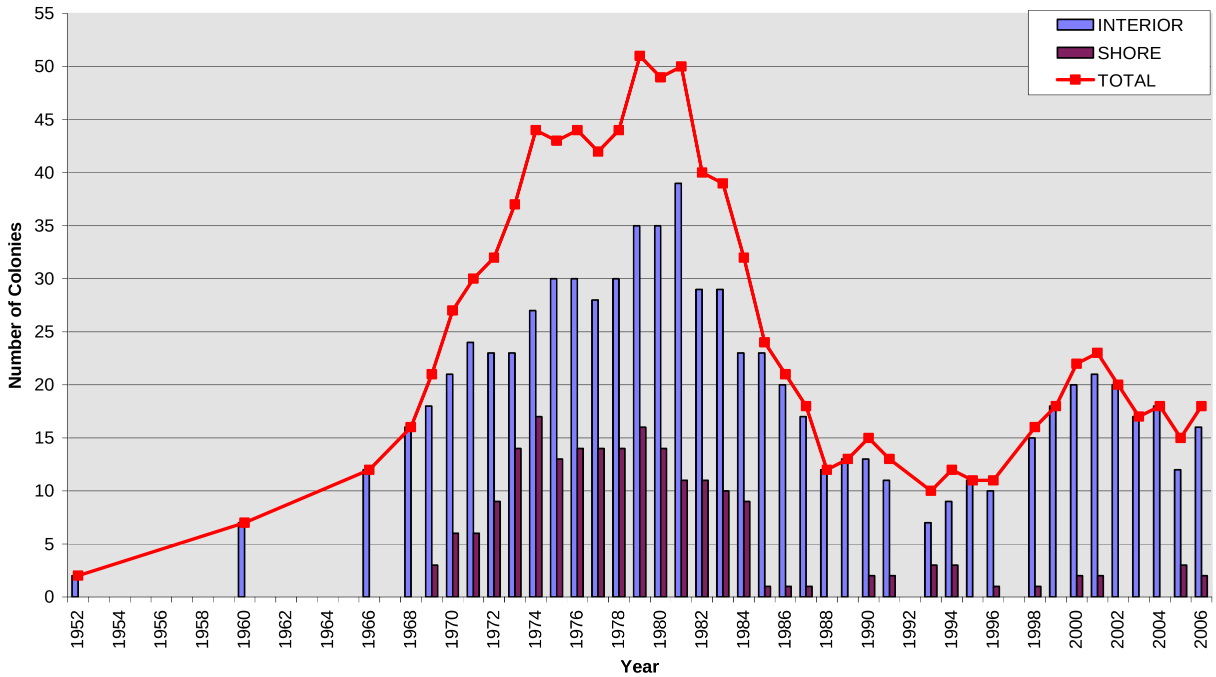
Beaver populations on Prescott Peninsula experienced 6 phases of growth and decline (**Figure 10**). From 1952 until approximately 1966, beaver populations on the Peninsula increased gradually. The number of colonies grew from 2 to 12. From 1967 until 1974, beaver populations entered their second phase which was characterized by a rapid increase in population. In only 7 years, beaver colonies increased from 12 to 44 colonies.

Between 1975 and 1982, the population was in its third phase characterized by high densities with some year to year fluctuation. The fourth phase of the population took place during 1983 to 1988. During this period, the number of beaver colonies decreased dramatically, from a high of 44 to a low of 12. Contributing to this overall decline was a reduction in the number of shoreline colonies. In 1983, there were 10 shoreline colonies, in 1987 there was only one and by 1988 there were no shoreline colonies present.

The fifth phase of the population lasted between 1988 and 1996. This phase is distinguished by relatively stable populations at low levels. The number of colonies during this period ranged between 10 and 15. In addition, this period had very few shoreline colonies.

The beaver population is currently in its sixth phase which has lasted since 1997. During this phase, populations increased slightly to a high of 23 in 2001. Since 2001, populations have declined slightly to a low of only 15 during 2005. As in phase 5, the number of shoreline colonies in phase 6 has remained relatively low.

Figure 10: Beaver Survey Results from Prescott Peninsula, 1952-2006



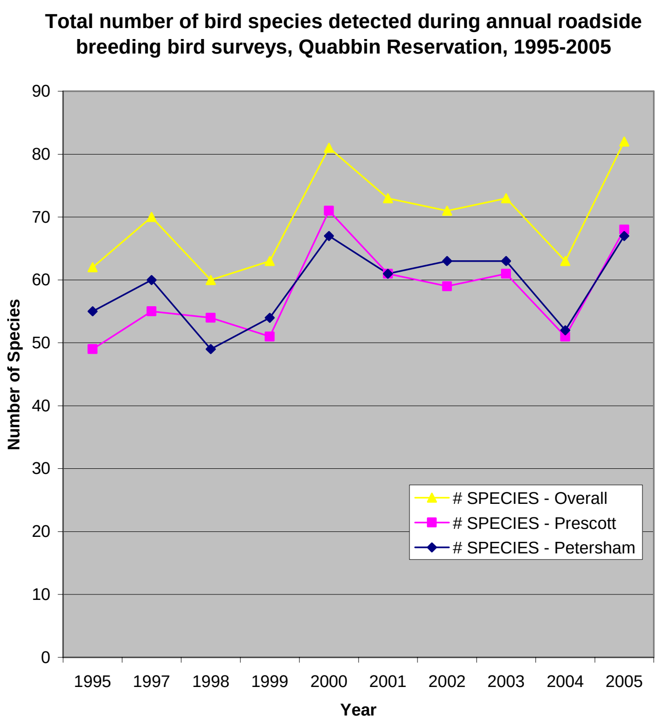
2.5.2.3 Roadside Breeding Bird Surveys

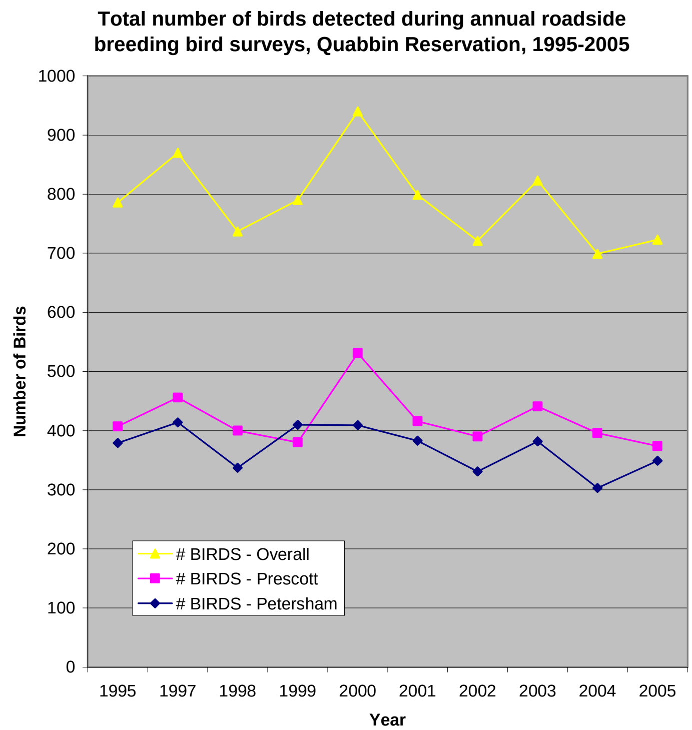
Roadside breeding bird surveys have been conducted yearly at Quabbin since 1988. Surveys are conducted along two routes. The first route is located in the Petersham area, and the second route is located on Prescott Peninsula. Stations are located adjacent to the interior roads and are approximately ½ mile apart. There are 16 stations on the Petersham route and 20 stations on the Prescott route. At each station, a listener and recorder note all individual birds either seen or heard during a three minute listening period. Surveys are conducted during early June each year to coincide with the active breeding period of migratory and resident birds.

Data from 1995 to 2005 indicate a slight increase in the number of bird species detected during the 10 year period (**Figure 11**). However, data also indicate a slight decline in the overall number of birds detected during this same period. While it appears that more species are being seen during the annual surveys, there are fewer individuals of those species being detected.

Data from roadside surveys can be useful in providing general trends in bird species and abundance; however, caution should be used when interpreting the data. Because survey stations were located adjacent to interior roads, results may not reflect species trends of forest interior migratory birds. Roadside surveys would favor edge species, common resident species, and species found in early successional non-forested habitat (several stations are adjacent to this habitat type).

Figure 11: Total Number of Birds and Bird Species Recorded During Annual Roadside Surveys, 1995-2005





2.5.2.4 Moose Survey

Annual surveys of moose sign (droppings, browsing evidence at least five feet above the ground, tracks, bark stripping, or moose beds) have been conducted on the Ware River watershed since 2002. In 2003, a moose sign survey was initiated at Quabbin on the Prescott Peninsula. Twenty-five monitoring plots were established and were visited during 23-25 April, 2003. Moose sign was detected on 11 plots (44%). The remaining 14 plots (56%) did not contain moose sign or contained sign that was greater than 1 year old. These surveys for moose sign are supplemented by observations of moose browsing (five feet above the ground, or breaking of tall saplings to reach browse) during annual regeneration surveys.

Since 2003, staffing issues have prevented the Quabbin moose sign survey from being done. However, efforts are being made to restart this program in the near future.

2.6 Quabbin Biological Diversity

2.6.1 Historic Trends

Habitat diversity generally drives biological diversity. The amount and types of habitat at Quabbin have been exceptionally dynamic since early colonial times. Dramatic changes in land use punctuated by periodic climatic events have shaped and changed the landscape and affected the number and types of habitats, plant communities, and plant and animal species. Once covered by virgin forest, the landscape was chronically altered by the activities of Native Americans, and a majority of the land in the Quabbin watershed was cleared for agriculture during colonial times. Land clearing and conversions persisted for decades, peaking around 1840 when 75 percent of the arable land in Massachusetts was in pasture or farm crops (DeGraaf et al., 1992). When agriculture dominated the landscape, species relying on extensive tracts of forest land were much less numerous. Black bears, wild turkeys, and white-tailed deer were gone from most of their former range. Bluebirds, bobolinks, vesper sparrows, and golden-winged warblers were abundant during this agricultural period, but today are very rare breeders. Field and brushland habitats and communities were more common than today, while forested communities were present but less common.

Through the late 1800s and into the early 20th century, farms were gradually abandoned as better lands and transportation opened in the West. White pine established itself in these abandoned fields and grew until the 1920s when extensive cutting took place to remove the pine. This represented the last large-scale land clearing in the region. Most of the cut pine sites regenerated to hardwoods, initially producing extensive tracts of early successional forested habitat. Among other species, ruffed grouse, rabbits, and a variety of songbirds flourished in this preferred habitat.

The 1938 hurricane blew down extensive areas of maturing forested habitat, particularly pine stands. This created additional areas of early successional forested habitat and species adapted to early successional habitat continued to thrive, while those species dependant on non-forested habitat became less common.

The last dramatic anthropogenic change to the Quabbin landscape took place during the 1930s when the reservoir was created. Approximately 24,000 acres of land were submerged when the reservoir was filled, creating 181 miles of shoreline (including islands) and a 412 billion gallon reservoir. While thousands of acres of terrestrial habitat were lost when the reservoir filled, a unique and important habitat was created. A variety of species benefited from the creation of the reservoir. Bald eagles and common loons began their statewide recovery at Quabbin.

Today, the vast majority of Division land within the Quabbin watershed is covered by maturing stands of trees of a variety of species. Very little of Quabbin is occupied by early successional forested or non-forested habitat. The broad and dramatic changes in the landscape during the last 300 years have shaped the current wildlife community. Species suited to mature forests with relatively closed canopies have thrived at Quabbin. White-tailed deer, turkey, moose, and a variety of forest interior song birds are abundant on the Reservation. On the other hand, species that were once abundant because of the extensive tracts of fields and young forests have declined substantially. Golden-winged warblers, upland sandpipers, eastern towhees, and grasshopper sparrows are now either absent from the landscape or are very uncommon.

2.6.2 Biodiversity: Current Conditions

2.6.2.1 General conditions

The forests, wetlands, water bodies, rock outcrops, islands, open areas, and other features within the Quabbin Reservoir watershed combine to form a landscape diverse in habitat conditions, although some habitats are certainly more common than others. In spite of its current “wild” appearance, the vast majority of this landscape was cut, grazed, or plowed at some point during the past 300 years of human use. While the forest has now recaptured the majority of the watershed, the legacy of past land use remains in

Epigaea repens, Trailing arbutus, the Massachusetts state flower.

both obvious (stone walls, roads, plantations) and less obvious (persistent changes in soil chemistry and physical properties; species composition) ways. The dominant habitat types are maturing forest cover and the massive water body of the reservoir, while open land areas and young forests are less common. The extensive list of floral and faunal species shown in **Tables 28-29** and **Appendix III** are supported by these dominant habitats as well and/or by a wide diversity of less common habitat types and natural communities.

2.6.2.2 Quabbin Flora, Common and Uncommon

During 1995 and 1996, the Division contracted with the University of Massachusetts Herbarium to inventory proposed harvesting areas for the presence of rare plant species. During this inventory, the Herbarium also compiled a general flora, a list of all species encountered. The list of the species encountered at Quabbin is included as **Appendix III.** Within this list, a small number of rare or uncommon species were encountered and populations of state-listed species have been located and recorded with Natural Heritage during independent surveys of Quabbin properties within the past 10 years (**Table 28**).

Table 28: State Listed Plants Occurring on DWSP Quabbin Properties

Species	**Common Name**	**Status**
Adlumia fungosa	Climbing Fumitory	T
Chenopodium simplex	Maple-leaf Goosefoot	WL
Clematis occidentalis	Purple or Mountain Clematis	SC
Gentiana linearis	Narrow-leaved Gentian	WL
Gentianopsis crinita	Fringed Gentian	WL
Juglans cinerea	Butternut	WL
Liatria scariosa var nova-angliae	New England Blazing Star	E
Mimulus moschatus	Musky Monkey-flower	T
Moneses uniflora	One-flowered Pyrola	WL
Panax quinquefolius	Ginseng	SC
Poa languida	Drooping Speargrass	E

NOTE: For Status, E = endangered, T = threatened, SC = special concern, WL = watch list

In addition to the rare or uncommon species highlighted above, there are uncommon species that have some likelihood of being found at Quabbin, were a comprehensive inventory initiated. These are listed in **Table 29**, and are based on historic records from the UMass herbarium and other sources.

Table 29: Uncommon Plants Potentially Occurring on DWSP Properties

Family	Species	Common Name	Status	Flowering
Apiaceae	*Conioselium chinense*	Hemlock Parsley	SC	Jul/Sep
Apiaceae	*Sanicula trifoliata*	Trefoil Sanicle	WL	Jun/Oct
Asclepiadaceae	*Asclepias verticillata*	Linear-leaved Milkweed	T	May/Jul
Asteraceae	*Aster radula*	Rough Aster	WL	Jun/Aug
Brassicaceae	*Arabis drummondii*	Drummond's Rock-cress	WL	May/Aug
Brassicaceae	*Arabis missouriensis*	Green Rock-cress	T	Jul/Oct
Brassicaceae	*Cardamine bulbosa*	Spring Cress	WL	Jun/Aug
Caryophyllaceae	*Stellaria borealis*	Northern Stitchwort	WL	May/Aug

Family	Species	Common Name	Status	Flowering
Cyperaceae	*Eleocharis intermedia*	Intermediate Spikerush	T	Aug/Oct
Cyperaceae	*Scirpus ancistrochaetus*	Barbed-bristle Bulrush	E	Jun/Jul
Fabaceae	*Lupinus perennis*	Wild Lupine	WL	May/Jul
Gentianaceae	*Gentiana andrewsii*	Andrew's Bottle Gentian	T	Apr/Jun
Gentianaceae	*Gentiana linearis*	Narrow-leaved Gentian	WL	Jun/Aug
Haloragaceae	*Myriophyllum alterniflorum*	Alternate-leaved Milfoil	T	Jun/Aug
Juncaceae	*Juncus filiformis*	Thread Rush	T	Aug
Lentibulariaceae	*Utricularia minor*	Lesser Bladderwort	WL	May/Nov
Liliaceae	*Smilacina trifolia*	Three-leaved Solomon	WL	Apr/Jun
Loranthaceae	*Arceuthobium pusillum*	Dwarf Mistletoe	SC	May/Sep
Orchidaceae	*Coeloglossum viride v. bracteata*	Frog Orchid	WL	May/Sep
Orchidaceae	*Corallorhiza odontorhiza*	Autumn Coralroot	SC	Apr/Jul
Orchidaceae	*Cypripedium calceolus v. parviflorum*	Small Yellow Lady Slipper	E	May/Aug
Orchidaceae	*Cypripedium calceolus v. pubescens*	Large Yellow Lady Slipper	WL	Jun/Sep
Orchidaceae	*Isotria medeoloides*	Small-whorled Pogonia	E	May/Jul
Orchidaceae	*Platanthera hookeri*	Hooker's Orchid	WL	Mar/Jun
Orchidaceae	*Platanthera macrophylla*	Large-leaved Orchis	WL	Apr/Jul
Orchidaceae	*Platanthera. flava var. herbiola*	Pale Green Orchis	T	Jun/Sep
Orchidaceae	*Triphora trianthophora*	Nodding Pogonia	E	Jul/Sep
Poaceae	*Panicum philadelphicum*	Philadelphia Panic Grass	SC	Jul
Poaceae	*Trisetum pensylvanica*	Swamp Oats	T	Aug/Oct
Poaceae	*Trisetum spicatum*	Spiked False Oats	E	Jul/Sep
Ranunculaceae	*Ranunculus alleghaniensis*	Allegheny Buttercup	WL	Jun/Sep
Sparganiaceae	*Sparganium angustifolium*	Narrow-leaved Bur Weed	WL	May/Nov
Urticaceae	*Parietaria pensylvanica*	Pellitory	WL	Aug/Sep

Working with the University of Massachusetts Herbarium, DWSP has also identified likely habitat/rare species relationships in the Quabbin area (**Table 30**). Some, but not all of these species have been located in the Quabbin area.

Table 30: Habitats in which Rare Species are Likely to be Found in the Quabbin Reservoir Watershed

Species	Common name	Comments
Forested Areas		
Rich Mesic Woods (less acid - rich herbaceous layer. Indicators: *Acer saccharum*, *Fraxinus americana*, *Adiantum pedatum*, *Asarum canadense*)		
Acer nigrum	Black Maple	
Cerastium nutans	Nodding Chickweed	
Coeloglossum viride v. bracteata	Frog Orchid	to dry rocky woods

Species	Common name	Comments
Corallorhiza odontorhiza	Autumn Coralroot	to dry/seasonally wet streamlets
Cypripedium calceolus v. pubescens	Large Yellow Lady Slipper	slopes and talus
Equisetum pratense	Horsetail	sandy places
Panax quinquefolius	Ginseng	talus and base of ledge areas
Platanthera hookeri	Hooker's Orchid	often rocky or swampy
Ranunculus alleghaniensis	Allegheny Buttercup	rocky
Ribes lacustre	Bristly Black Current	
Sanicula canadensis	Canadian Sanicle	
Sanicula gregaria	Long-Styled Sanicle	
Sanicula trifoliata	Trefoil Sanicle	
Moist Coniferous/Pine Woods		
Goodyera repens	Dwarf Rattlesnake Plantain	pine woods
Moneses uniflora	One-Flowered Pyrola	moist rich woods
Hemlock-Northern Hardwoods		
Isotria medeoloides	Small-whorled Pogonia	vernally moist areas
Platanthera macrophylla	Large leaved Orchis	moist ravines, limey
Rhododendron maximum	Rhododendron	hemlock island in swamp
Triphora trianthophora	Nodding Pogonia	depressions under beech
Viola renifolia	Kidney Leaved Violet	damp rich woods
General Habitat		
Boulder/Talus Slope/Ledges		
Adlumia fungosa	Climbing Fumitory	shaded limey talus
Amelanchier sanguinea	Roundleaf Shadbush	ledges & ridge tops
Arabis drummondii	Drummond's Rock-cress	
Arabis missouriensis	Green Rock-cress	open rock and scree
Chenopodium gigantospermum	Maple-leaf Goosefoot	shaded dry ledges
Clematis occidentalis	Purple Clematis	exposed ledges & talus
Parietaria pensylvanica	Pellitory	shaded shelves
Pinus resinosa	Red Pine (as native)	exposed, rocky ridge tops
Rosa blanda	Smooth rose	dry to mesic rocky slopes
Trisetum spicatum	Spiked False Oats	exposed
Sandplain / Open Meadow		
Asclepias verticillata	Linear-leaved Milkweed	open rocky
Eragrostis capillaris	Lace Love Grass	open sandy soil
Gentiana andrewsii	Andrew's Bottle Gentian	open/meadow
Liatris scariosa var novae-angliae	New England Blazing Star	sandy open pine wds.
Lupinus perennis	Wild Lupine	sandy open pine wds.
Paspalum setaceum	Paspalum	sandy soil
Penstemon hirsutus	Beard-Tongue	dry or rocky ground
Polygala verticillata	Whorled Milkwort	open woods/old field/stony shores
Aquatic Habitats		
Ponds / Streams		
Aster tradescantii	Tradescant's Aster	fields/swamps
Betula nigra	River Birch	swamps & stream banks
Cardamine longii	Long's Bitter-cress	swampy streams
Eleocharis intermedia	Intermediate Spikerush	exposed shores
Juncus filiformis	Thread Rush	meadows/springs/riverbank
Megalodonta beckii	Water Marigold	

Species	Common name	Comments
Myriophyllum alterniflorum	Alternate leaved Milfoil	
Nuphar pumila	Tiny Cow-Lily	
Panicum philadelphicum	Philadelphia Panic Grass	exposed shores
Scirpus ancistrochaetus	Barbed-bristle Bulrush	swales and shores
Sparganium angustifolium	Narrow-leaved Bur Weed	
Sparganium fluctuans	Bur-Reed	
Utricularia minor	Lesser Bladderwort	seepy stream sides
Utricularia resupinata	Bladderwort	swamps, swales, shores
Seeps/Seepage Areas		
Cardamine bulbosa	Spring Cress	
Conioselium chinense	Hemlock Parsley	black ash seepage swamps
Cypripedium calceolus v. parviflorum	Small Yellow Lady Slipper	black ash seepage swamps
Elatine americana	American Waterwort	wet clay soil
Mimulus moschatus	Muskflower	open seepage area
Pedicularis lanceolata	Lousewort	open areas
Platanthera flava var. herbiola	Pale Green Orchis	vernal streams in hardwoods
Stellaria borealis	Northern Stitchwort	
Trisetum pensylvanica	Swamp Oats	
Bogs/Boggy Areas		
Arceuthobium pusillum	Dwarf Mistletoe	grows on Black Spruce
Arethusa bulbosa	Arethusa	
Aster radula	Rough Aster	beaver meadows/swamp borders
Gentiana linearis	Narrow-leaved Gentian	boggy meadows
Scheuchzeria palustris	Pod Grass	
Smilacina trifolia	Three-leaved Solomon	boggy woods
Viola nephrophylla	Northern Bog Violet	
Xyris montana	Northern Yellow-eyed Grass	

2.6.2.3 Rare, Uncommon, and Exemplary Natural Communities

Natural communities have been defined in a variety of ways. Some definitions include only abiotic features, while other definitions rely primarily on the dominant vegetation of an area. Combining these approaches, natural communities can be defined as an assemblage of both biotic and physical conditions that occur together to form a functionally distinct area of the landscape. These unique assemblages caused by the combination of physical environment, biological interaction, and disturbance will dictate the type and extent of vegetation present, which in turn will shape the faunal community. The Quabbin watershed harbors a wide array of unique natural communities. Some of the communities are rare on a regional or global level. From 1997 to 2000, in response to a recommendation by the FSC forest certification auditor that the biological diversity at Quabbin should be better characterized, the University of Massachusetts Department of Natural Resources Conservation, under the primary direction of Associate Professor Kevin McGarigal, assessed the watershed for rare, uncommon, and exemplary natural communities. The purpose of this study is described in a September 2000 report entitled “Rare, Uncommon, and Exemplary Natural Communities of Quabbin Watershed”: “to identify, classify, and describe the rare, unique, and exemplary natural communities in the Quabbin watershed area of Massachusetts and to provide recommendations for their management.” The report identifies, and describes in detail, 22 rare communities in the Quabbin watershed. They include the following communities indicated by bold type:

TERRESTRIAL COMMUNITIES

- Terrestrial communities on exposed rock and shallow soils
  - Bedrock outcrops, summits, ridgetops and cliffs: ***Vaccinium* shrubland; *Juniperus virginiana* shrubland**
  - Talus slopes: **Talus slope community**
- Terrestrial communities on deep soils
  - Dry forests / well-drained soils
    - Sandy soils: ***Pinus rigida - Quercus ilicifolia* woodland**
  - Mesic forests / moderately well-drained soils
    - Sandy-loams to loams: ***Tsuga canadensis* -dominated forest**
    - Loams to silt-loams: ***Acer saccharum - Fraxinus americana - Tilia americana* forest**

RIPARIAN COMMUNITIES

- Streamside communities
  - High-gradient stream communities: ***Tsuga canadensis*-dominated stream community**
  - Low-gradient stream communities
    - Forest streamside communities: ***Tsuga canadensis*-dominated stream community**

PALUSTRINE COMMUNITIES

- Wetlands on mineral or muck soils
  - Basin and seepage wetlands
    - Temporarily flooded wetlands
      - Non-vegetated wetlands: **Vernal/autumnal pool**
      - Shrub swamps: **Kettlehole shrub swamp**
      - Forested swamps: ***Nyssa sylvatica* swamp; *Fraxinus nigra* swamp; *Picea mariana* swamp**
  - Fringe wetlands
    - Temporarily flooded wetlands
      - Forested swamps: ***Nyssa sylvatica* swamp; *Fraxinus nigra* swamp; *Picea mariana* swamp**
- Wetlands on peat
  - Basin and seepage peatlands
    - Herbaceous peatlands: **Poor fen**
    - Shrub peatlands: **Bog/acidic fen**
    - Forested peatlands: **Bog transition forest**
  - Fringe peatlands
    - Herbaceous peatlands: **Poor fen**
    - Shrub peatlands: **Bog/acidic fen**
    - Forested peatlands: **Bog transition forest**

The status of these communities at Quabbin and globally has been evaluated and is shown in **Table 31**.

Table 31: Status of Rare Communities on the Quabbin Reservoir Watershed

COMMUNITY	Global Status	Status at Quabbin	Threats
Terrestrial			
Vaccinium shrubland	Secure	Rare	Foot traffic, invasive plants
Red Cedar shrubland	Regionally rare	Rare	Foot traffic; invasive plants
Talus slope	Unknown	Uncommon	Disturbance above slope, invasive plants
Pitch Pine – Scrub Oak	Regionally rare	Rare	Fire suppression
Hemlock dominated forests	Unknown	Common	Hemlock wooly adelgid
Sugar Maple-White Ash-American Basswood forest	Secure	Uncommon	Invasive plants
Riparian			
Hemlock stream communities	Unknown	Common	Hemlock wooly adelgid
Palustrine			
Black Tupelo swamp	Very rare	Extremely rare	Beaver flooding; physical disturbance
Black Ash swamp	Very rare	Uncommon	Beaver flooding; physical disturbance
Black Spruce swamp	Uncommon	Uncommon	Beaver flooding; physical disturbance
Vernal pools	Unknown	Common	Disturbance to adjacent uplands
Peat, bog, fen, swamp shores	Very rare	Uncommon	Beaver flooding; invasive plants; trampling

Many of these rare communities are threatened to some extent by invasive plants or insects, as well as by pressures from increasing populations of native wildlife, such as beaver, deer, or moose. In some cases, watershed management activities have the potential to affect these areas positively or negatively. It is an abiding objective of DWSP to work to better understand these communities and to avoid negative impacts resulting from watershed management practices.

2.6.2.4 Rare Wildlife Species and Habitats

Division property within the Quabbin watershed is inhabited by a number of state-listed vertebrate species (**Table 32**). Rare species surveys often (and logically) focus on lands that are most actively threatened by development, rather than on large protected public holdings. The Division conducts general and some targeted surveys that discover new populations of listed species (plant and animal), but it is likely that there are undiscovered populations of rare and endangered species on Division property. Although land protection is the most critical factor for their survival, the Division recognizes the value in knowing where these species are located, in order to set priorities for specific protection measures and to guide management activities in or near critical habitats.

In order to ensure that land management activities do not disrupt or destroy listed species or their habitats, it is a Division objective to develop a more complete and current species occurrence database. DWSP's Natural Resources Section keeps records of listed plant and animal species on Division land that were discovered by in-house personnel or passed along by other professionals or the public. The MA Natural Heritage and Endangered Species program (NHESP) maintains more complete and detailed databases of listed species. Timber harvesting carried out by the Division is reviewed by a Service Forester, who passes the cutting plan to NHESP when the harvesting map intersects a mapped Priority Habitat or Estimated Habitat for rare species (NHESP, 2006). NHESP sets restrictions on the harvesting activity if necessary to protect the species of concern. Routine maintenance (mowing, brush cutting) or watershed maintenance activities (road building/repair) are not required to file with NHESP. In these situations, it is possible to unknowingly and negatively impact rare or endangered species, but the Division is working to prevent this from happening through cooperation with NHESP to identify and map areas of concern that may be impacted. The Division is working with NHESP to improve staff awareness of rare species presence in order to prevent unintended impacts.

In many cases, rare and endangered species became rare because of loss of habitat or are further threatened by these losses. One of the greatest benefits of Division land to rare species is that it will remain undeveloped in perpetuity. As the majority of this land is covered by forest, it is of greatest benefit to rare or endangered species requiring forested habitat (sharp-shinned hawk, Cooper's hawk, Acadian flycatcher). Approximately half the species listed in **Table 32** are either dependent on wetlands or utilize them during some portion of their lives. Protecting and maintaining functioning wetland systems is a priority for the Division, which should benefit wetland species. In addition, vernal pools on Division land receive particular attention and protection (see section 5.2.5.7 and **Figure 18**). Further, current MA Conservation Management Practices (CMPs) for vernal pools have recently been revised to improve their effectiveness in protecting vernal pool dependent species.

Non-forested upland habitat is much rarer on Division property and is limited to maintained open spaces. There are several species on **Table 32** that require open fields or meadows. Although the Division will not create new field habitat, the importance of this habitat in the landscape is recognized. Therefore, where feasible, the Division will maintain and enhance this habitat where it exists on its land (see Section 5.5.5.4.1).

Areas with highly disturbed soils represent important habitat for several species listed in **Table 32**. On Division land there are several large active and inactive gravel and sand pits and areas of exposed stream banks and shoreline. Wood, Blanding's, and Box turtles use sandy or gravelly areas to lay their eggs. In addition, some invertebrates such as the Big Sand Tiger Beetle, Dune Ghost Tiger Beetle, Oblique-lined Tiger Beetle, Frosted Elfin, and Hoary Elfin utilize areas of highly disturbed soils. The Division recently documented Wood Turtles laying eggs in an abandoned Division sand pit. In many cases, however, these highly disturbed areas are scheduled for restoration (see Section 5.3.2.2). The Division recognizes the potential wildlife value some of these areas have, and in the future the Division will examine each site on a case-by-case basis to determine: 1) actual erosion threat, and 2) habitat suitability for selected wildlife species. In some cases, where erosion is not a threat, the site may be abandoned and left in its disturbed state.

Table 32: Status of State-listed Vertebrate Species whose Ranges Overlap DWSP Quabbin Properties

SPECIES	STATUS[1]	OCCURRENCE[2]
AMPHIBIANS		
Blue-Spotted Salamander	SC	Documented
Jefferson Salamander	SC	Documented
Marbled Salamander	T	Documented
Spring Salamander	SC	Documented
Four-Toed Salamander	SC	Documented
Eastern Spadefoot	T	Potential
REPTILES		
Spotted Turtle	SC	Documented
Wood Turtle	SC	Documented
Blanding's Turtle	T	Documented
Eastern Box Turtle	SC	Documented
Eastern Wormsnake	T	Potential
Eastern Ratsnake	E	Potential
Copperhead	E	Historic
Timber Rattlesnake	E	Historic
BIRDS[3]		
Common Loon	SC	Documented
Pied-Billed Grebe	E	Potential
American Bittern	E	Documented
Least Bittern	E	Documented
Bald Eagle	E	Documented
Northern Harrier	T	Potential
Sharp-Shinned Hawk	SC	Probable
Peregrine Falcon	E	Historic
King Rail	T	Potential
Common Moorhen	SC	Potential
Upland Sandpiper	E	Historic
Common Barn Owl	SC	Historic
Long-Eared Owl	SC	Probable
Short-Eared Owl	E	Historic
Sedge Wren	E	Historic
Golden-Winged Warbler	E	Probable
Vesper Sparrow	T	Probable
Grasshopper Sparrow	T	Probable
Henslow's Sparrow	E	Historic
MAMMALS		
Water Shrew	SC	Documented
Southern Bog Lemming	SC	Documented

[1] Species status in Massachusetts: SC= species documented to have suffered a decline that could threaten the species if allowed to continue unchecked; T = species likely to become endangered within the foreseeable future throughout all or a significant portion of its range; E = species in danger of extinction throughout all or a significant portion of its range.
[2] Occurrence of species on Division land within the watershed: Documented =species actually observed; Probable =species not documented, but given available habitat, species' range, and/or observations within the watershed, they are likely to occur; Potential =species not documented, and current habitat conditions may not be suitable, but with habitat enhancement they may occur; Historic= documented presence in the past, but has not recently been seen and may not be supported by current conditions.
[3] Occurrence of birds is limited to breeding pairs, not migratory or seasonal residents.

2.7 Quabbin Cultural Resources

Cultural Resources may be divided into four principal categories: historic records and documents, historic buildings and structures, historic or cultural landscapes, and archaeological resources (prehistoric and historic). Due to their varied nature, the many features and materials that can be classified as "cultural resources" at Quabbin require a multi-disciplinary management approach. Cultural Resources range from individual historical documents to artifacts of ordinary life during many centuries of human occupation of the Swift River Valley, to entire landscapes. In some cases, there is overlap between categories; for example, a stone wall is a construction but may also be a significant component of a cultural landscape. In many cases, there is room for interpretation and debate about the value of specific cultural resources and the importance or feasibility of preservation.

2.7.1 Records and Documents

Upon dissolution of the Swift River Valley towns prior to construction of the Reservoir, the Quabbin Superintendent became Town Clerk for Dana, Greenwich, Prescott and Enfield. Each Superintendent (now Regional Director) has held this office and has been responsible for maintaining the Vital Records of previous inhabitants of the Valley towns. Copies of these records are stored at the Quabbin Administration Building and are available to the public for research purposes. Similarly, the original survey "Taking Sheets," and photographs and records of each property purchased by the Commonwealth prior to the actual Reservoir construction, are archived in the Quabbin Engineering Office. For educational outreach purposes, DCR staff frequently draw upon in-house collections of artifacts as well as the extensive records of Reservoir construction and the early management of the watershed lands; including, for example, the development of a tree nursery and the establishment of plantations for water quality protection. In addition, an estimated 20,000 guests see educational displays at the Quabbin Visitor Center each year.

2.7.2 Buildings and Structures

There is a long history of human occupation and construction on Quabbin watershed lands (see Archaeology, below). DCR field staff, historians, area residents, and members of the Swift River Valley Historical Society continue to add to our knowledge and growing database of physical sites such as foundations, wells, mill sites, and cellar holes.

Between 1994 and 1998, a series of graduate students from the Department of Archaeology at Boston University created a "historical sites inventory" for the Quabbin watershed. The interns used a review of historical documentation (including the Quabbin "Taking Sheets," and 19th century Atlases) and information collected from foresters and local archaeological enthusiasts, to record 867 sites, many of which were visited in the field.* DCR staff digitized the site locations, and the presence and preservation of these features is included in planning for all forestry operations. Before any harvest takes place on a site or "lot," DCR Foresters circulate a detailed Lot Proposal for internal and public review. The Proposal includes information on cultural resources present on the proposed harvest site.

The following example of Cultural Resources identification and planned management action is taken from a Fiscal Year 2007 Lot Proposal:

> *Very nice cellar hole and associated walls on the Lot, right on the road. An interesting feature: the blown-down locust stand in the old pasture south of the cellar hole. These*

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* Based on the original survey sheets, DCR subsequently digitized nearly one thousand additional historic site locations, most of which are now under water.

trees would have originated from sheep eating locust pods and depositing the seeds around the pasture. These large trees blew down in the 1938 Hurricane, suggesting that the area was abandoned as pasture well before the General Taking.

A forwarder will be used on the lot to minimize ground disturbance. (from Lot Proposal Form PE-07-10A, Steve Ward, DCR Forester)

In his review of Quabbin Lot Proposals for Fiscal Year 2007, DCR Archeologist Tom Mahlstedt subsequently identified this cellar hole as "the remains of the Benson Farmstead, which was occupied in the mid-1800s."

2.7.3 Landscapes and Landscape Features

A cultural landscape is defined as "a geographic area, including both cultural and natural resources and the wildlife or domestic animals therein, associated with a historic event, activity, or person or exhibiting other cultural or aesthetic values."[*] Cultural landscapes, sometimes called "heritage landscapes," include historic sites (such as battlefields), historic designed landscapes (such as estates and parks), historic vernacular landscapes (which can range in scale from a single farm to an industrial complex), and ethnographic landscapes (such as ceremonial grounds). These designations are not mutually exclusive.

These landscapes convey aspects of our shared history that forge our cultural identity. Heritage landscapes also reflect ecological and environmental conservation concerns, affect the real estate market, and attract tourism and recreation….Once we begin to look with an informed view, we see the wealth of knowledge that such landscapes convey about our community's past, the emotional connection many have to certain places, and how this awareness can improve our communities and our lives.[†]

Charles A. Birnbaum, Landscape Architect for the National Park Service, writes of undertaking projects to ensure a successful balance between historic preservation and change: "Wise stewardship protects the character, and/or spirit of a place by recognizing history as change over time. Often, this also involves our own respectful changes through treatment."

2.7.3.1 Historical vernacular landscapes

Historical vernacular landscapes evolve through use by the people whose activities or occupancy shaped that landscape. Through social or cultural attitudes of an individual, family or a community, the landscape reflects the physical, biological, and cultural character of those everyday lives. Function plays a significant role in vernacular landscapes. They can be a single property, such as an orchard, or a collection of properties such as a district of historic farms along a river valley.[‡] Examples include rural villages, industrial complexes, and agricultural landscapes.

Nearly all designed and vernacular landscapes evolve from, or are dependent on, natural resources. It is

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* This definition and much of the information on cultural landscapes is taken from: Birnbaum, Charles A. Preservation Brief 36: Protecting Cultural Landscapes: Planning, Treatment and Management of Historic Landscapes 1994 Technical Preservation Services, National Park Service, U.S. Department of the Interior.
† Reading the Land –Massachusetts Heritage Landscapes: A Guide to Identification and Protection, p6. DCR staff received the 2004 Public Education Award from the American Planning Association for publication of this Guide.
‡ Terra Firma 2: Putting Historic Landscape Preservation on Solid Ground. Massachusetts Department of Conservation and Recreation. 2006. Pg 3.

the dynamic qualities of these interconnected systems of land, air and water, vegetation and wildlife that differentiate cultural landscapes from other cultural resources, such as historic structures. However, such structures sometimes form a significant feature of a cultural landscape. The stone remains of mill sites found on the Quabbin watershed and throughout New England testify to the direct relationship between natural resources and the history of human land use in the region.[*]

Prior to the taking of land for the Quabbin Reservoir, much of the Swift River Valley was agricultural land – either pasturage or tillage. Since DCR has chosen managed forest cover to provide the most effective protection of the watershed and water supply, the earlier vernacular landscape has not been maintained or recreated on watershed lands. However, areas have been identified as representative of "primary forests" or "historical woodlots"; acreage that, even during the height of agricultural clearing, was retained as forest to provide timber and fuel, or simply because it was difficult or impossible to develop for agriculture.

2.7.3.2 Landscape Features

While a stewardship approach may be applied to an entire landscape, it can also be used to address a single feature, such as a perennial garden or a family burial plot. Within cultural landscapes, plants may have historical or botanical significance. A tree may have been associated with a historic figure or event or be part of a notable landscape design.[†] A plant or plant population may be an uncommon cultivar, exceptional in size or age, rare or commercially unavailable. In addition to their daily forest management responsibilities, DCR foresters selectively preserve historically and botanically significant plants and trees; for example, the occasional American Chestnut that has survived the Chestnut Blight to reach reproductive age or an ornamental planting of a native plant. Acorns from exceptionally productive oaks are collected and planted. A small apple orchard, struggling survivor of a now-vanished homestead, is given adequate care to enable its survival amidst more competitive vegetation, thus providing both a living reminder of the history of the area and a valuable source of food for Quabbin wildlife.

In general, historic roads across the Commonwealth are subject to public pressure for change, due to increased traffic volume, local construction and development, and related safety concerns.[‡] In contrast, the land management strategy at Quabbin has effectively preserved a road and by-way pattern that developed over centuries of human land-use in the Swift River Valley, frequently highlighted by well-preserved stonewalls.

2.7.4 Archaeological Resources: Prehistoric

Archaeological evidence suggests that human occupation of the Swift River region may have been continuous for as long as 12,000 years. While evidence of this occupation has mostly been obscured by more recent land use, where such evidence remains, it is exceptionally precious for its link to the distant past.

2.7.4.1 Prehistoric Overview

Paleo Indian hunters and gatherers reached the Swift River drainage 9,500 to 12,000 years ago. Based on the presence of diagnostic Eastern fluted points in a local artifact collection, one northern Quabbin site has been tentatively identified as belonging to the Paleo Indian period. The site may have been near a

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* Paul Bigelow, Wrights and Privileges: the Mills and Shops of Pelham, Massachusetts, from 1740 to 1937, 1993, Haleys, Athol, MA.
† Terra Firma 2. p. 3.
‡ Terra Firma 3: Putting Historic Landscape Preservation on Solid Ground. Massachusetts Department of Conservation and Recreation. 2006. Pg 6-7.

glacial lake at a time when the landscape was changing from barren and tundra-like conditions to a spruce parkland-spruce woodland community (Davis 1969; Davis 1983).

By about 9,000 years ago the warming climate had created an environment in southern New England that supported a mixed pine-hardwood forest (Davis 1969; Davis 1983). Three archaeological sites along the Middle and East Branches of the Swift River indicate that human occupation of the northern Quabbin area continued during the Early Archaic period (ca. 9,500 to 8,000 years ago).

During the Middle Archaic period (ca. 8,000 - 6,000 years ago) the mixed deciduous forests of southern New England became established, and the present migratory patterns of many fish and birds may have developed (Dincauze 1974). Quabbin waterways utilized by anadromous fish for spawning may have led to seasonal fishing encampments of Native American groups; this was a subsistence strategy persisting throughout prehistory. Evidence of Native American occupation of the Quabbin region during Middle Archaic times comes from four sites, all of which were also occupied in earlier and/or later periods.

At least twenty-four sites within the Quabbin watershed have yielded diagnostic Late Archaic period materials. The marked increase in site frequencies and densities is consistent with findings throughout most of southern New England, and may reflect a population increase ca. 6,000 to 3,000 years ago. Each of the three traditions - the Laurentian, Susquehanna and Small Stemmed Traditions - is well represented in the archaeological record of local sites. Terminal Archaic activity (ca. 3,000 - 2,500 B.P.) is suggested at three sites, including a steatite (a type of soapstone) quarry.

Evidence of Native American occupation during the Early, Middle and Late Woodland periods (3,000 - 450 B.P.) comes from five Quabbin sites from each period. Regionally, horticulture was introduced during the Early Woodland period and small gardens may have been planted in clearings located on the fertile alluvial terraces next to the Swift River and its larger tributaries. Settlement is likely to have occurred on virtually any elevated, level and well-drained surface adjacent to a source of fresh water, including the headwaters of ephemeral streams, springs, and small wetlands and ponds. Rock shelters and other natural overhangs, and locations with southerly exposures, may also have been utilized.

2.7.4.2 Prehistoric Archaeological Interpretation

The cumulative archaeological evidence indicates that this portion of Massachusetts has been occupied more or less continuously since Paleo Indian times (ca. 12,000 - 9,000 years ago). Currently, the Massachusetts Historical Commission (MHC) has records for fifty prehistoric sites on Quabbin lands managed by the DCR Division of Water Supply Protection. Although the MHC's records are the most complete archaeological data bank in the state, these sites represent a 10,000-year span and therefore a great deal of sample error, and there is a strong likelihood that more sites remain undiscovered. All of the sites currently recorded in the Quabbin watershed were discovered by local artifact collectors exploring areas exposed when the waters of the reservoir were unusually low. Interior sites have yet to be explored.

Most of the known prehistoric sites in the former Swift River Valley and along its tributaries have been disturbed by subsequent human land-use. There is little substantive information regarding the formation processes and behavior responsible for creating these sites. Twenty-five of the fifty recorded sites within the Quabbin watershed are known by location only, with no indication of the type or range of artifacts and features that were encountered.

However, analysis of artifacts from the better-documented Quabbin sites reveals a pattern of multiple, recurrent occupation; few sites have yielded artifacts from a single cultural/temporal period. This suggests that recurrent, though intermittent occupation or utilization of a single site, sometimes over a period of several thousand years, may have been the prevalent pattern of prehistoric site development in this region. By analyzing the existing data in the context of current archaeological theory, predictions of archaeologically sensitive areas and the expected type and range of prehistoric settlement in the Quabbin region have been formulated. The possibility of prehistoric site presence, based upon a model of topography and proximity to water, is one consideration in proposed silvicultural operations at Quabbin (see Section 5.6.1, Silviculture and Cultural Resource Management: Prehistoric Sites).

2.7.5 Archaeological Resources: Historic

European settlement in the Swift River Valley began in 1736, when the General Court made a grant of 1,000 acres of land for the Quabbin territory, and the development of both water-powered industries and agriculture began. The first church in the Swift River Valley was erected in Greenwich Plains in 1744, and Quabbin parish was incorporated in 1749. Shay's Rebellion occurred in 1787 and was plotted in Conkey's Tavern in what would eventually be incorporated as the town of Prescott. Greenwich was incorporated in 1754, Dana in 1801, Enfield in 1816, and Prescott in 1822. By 1822 the four towns had a combined population of about 3,000 (**Table 33**).

With the passage of the Swift River Act in 1927, the four valley towns were slated for disincorporation and their lands were purchased by the Commonwealth in the General Taking prior to construction of the Quabbin Reservoir. Together with additional land from adjacent towns, the state acquired a total of 80,433 acres by 1938, the official date of disincorporation of the four towns. During this time 650 houses and 450 other structures were removed from the Swift River Valley. Many buildings were relocated to other communities, in some cases as far away as Vermont. Some cellar holes were filled, leaving little or no trace of their existence, a practice that was particularly prevalent in Prescott.

Table 33: Population of Swift River Valley, 1830-1938

Date	Dana	Enfield	Greenwich	Prescott	Total
1830	623	1,056	813	758	3,250
1900	790	1,036	491	380	2,697
1920	599	790	399	236	2,024
1930	595	497	238	48	1,378
1935	387	495	219	18	1,119
1938	All four towns disincorporated				0

(Source: Quabbin Facts & Figures, published by the Friends of Quabbin, Inc. and the MDC, ca.1990)

2.7.5.1 Stone Walls

Perhaps the most common historic construction on the Quabbin landscape is the ubiquitous stone wall, lining the roads and tracing a far-flung pattern over hill and across valley. Often definable as both a construction and a cultural landscape component, stone walls are sometimes considered iconic; a rock-solid legacy of the earliest European settlers. This popular image has been challenged by Robert Thorson, a professor of geology and geophysics at the University of Connecticut. Thorson is a strong advocate for the preservation and informed appreciation of stone walls, but in his book, Stone By Stone: The Magnificent History in New England's Stone Walls, Thorson defines the construction of stone boundary walls as a late-18th to 20th-century undertaking, rather than a colonial occupation. He presents a pragmatic view: "However tidy well-built walls might appear, most functioned originally as linear landfills, built to hold nonbiodegradable agricultural refuse."* Also, contrary to the idea that preserving

* Thorson, p. 6.

stone walls is largely a matter of leaving them intact, Thorson asserts, "Left untended, every wall will come apart, tumble to the ground, disperse over acres of soil, and be buried by encroaching vegetation."*

In addition to their value as cultural resources and a link to the agricultural past, DWSP has funded their study by University of Massachusetts Landscape Ecologist Kevin McGarigal to determine the role of stone walls as wildlife habitat. In a report provided to the Division in 2000, Dr. McGarigal states the problem as follows:

> *The presumed ecological effects of stone walls are related to their distinctive linear structure and the spatial patterns these structural corridors impose on the broader landscape. Despite the clear impacts of stone walls and other linear features on the physical structure of the landscape, it is largely unclear whether stone walls function as corridors to affect landscape connectivity for organisms either by providing breeding habitat for individuals and thus serving to connect larger populations units by maintaining gene flow; by providing dispersal and/or migratory pathways and thus serving to facilitate movement of organisms among habitats; or by serving as barriers or filters that prevent or impede the movement of organisms across the corridor.*

At Quabbin, Dr. McGarigal studied vertebrate movements at specific locations in stone walls located in mature forests and captured 18 separate animal species using the walls as habitat. The movement and breeding of small mammals seemed to be facilitated by the cover provided by stonewalls, while amphibians and reptiles seem to simply move through the walls on their way to breeding habitats.

Stone walls are offered some protection by State law in Massachusetts. Ch. 40, Section 15C requires a public hearing process before stone walls can be removed or destroyed on any road designated as a "scenic road." They are protected as "property" against destruction or removal (Ch. 266, Section 105) and as "natural scenery" against defacement (Ch. 266, Sections 126 and 126B). The latter applies not only to stones and stone walls, but also to gravestones, buildings, walls, monuments; in effect, the favorite targets of graffiti "artists." Where stone walls are part of a dam, waterway or mill site, they may also be protected under Ch. 266, Section 138, which addresses "malicious injury" to dams and reservoirs. DWSP affords protection for historic features both to meet statutory obligations and out of respect for the displaced former residents whose families once called these areas home. Efforts are currently underway to improve the mapping and general awareness of stone walls on the Quabbin landscape.

2.7.5.2 Wells and Cellar Holes

Unlike the miles of stone walls apparent throughout the Quabbin watershed, many constructed features are discovered only by stumbling upon them – sometimes literally, as in the unfortunate example of wells which are often found when a walker's foot suddenly drops straight down into a deep, narrow hole made invisible by an accumulation of forest debris. Although stone foundations, wells, and cellar holes often occur in obvious locations, there are examples in remote and relatively inaccessible places that would only be found by coming across them unexpectedly. Because DCR Foresters walk every square mile of managed forest in the course of their duties at Quabbin, they are the most likely to discover and identify these features. GPS technology provides the possibility of pinpointing these features as they are discovered.

* Thorson, p. 9.